

Ref B

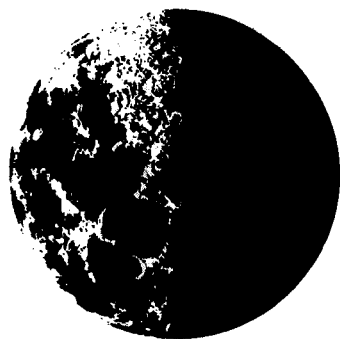


SID 64-20

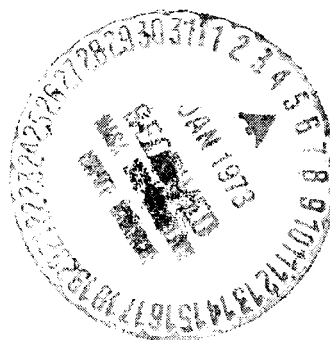
SUBSYSTEM DEVELOPMENT PLAN—
INSTRUMENTATION

NAS9-150

31 March 1965



APOLLO



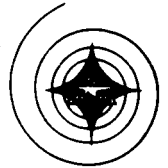
Accession No. _____

SID 64-2061

SUBSYSTEM DEVELOPMENT PLAN—
INSTRUMENTATION

NAS9-150

31 March 1965



NORTH AMERICAN AVIATION, INC.
SPACE and INFORMATION SYSTEMS DIVISION



TECHNICAL REPORT INDEX/ABSTRACT

ACCESSION NUMBER				DOCUMENT SECURITY CLASSIFICATION			
				Unclassified			
TITLE OF DOCUMENT						LIBRARY USE ONLY	
Subsystem Development Plan - Instrumentation							
AUTHOR(S)							
Instrumentation Design Group							
CODE	ORIGINATING AGENCY AND OTHER SOURCES			DOCUMENT NUMBER			
	Apollo Engineering - Instrumentation			SID 64-2061			
PUBLICATION DATE			CONTRACT NUMBER				
March 31, 1965			NAS9-150				
DESCRIPTIVE TERMS							
Instrumentation		Acceptance tests Qualification tests Major ground tests Flight vehicles Laboratory system			Off-limit tests Test conditions		

ABSTRACT

The Instrumentation Subsystem Development Plan (SDP) provides a test program to ensure that the instrumentation equipment will perform to mission requirements.

The SDP provides the analysis and testing required for lunar orbital rendezvous (LOR) qualification. In addition to providing general direction for planning, provisioning, and development activities of S&ID and its sub-contractors, the SDP provides requirements for integrated subsystem tests in ground and flight test vehicles.



CONTENTS

Section		Page
1.0	INTRODUCTION	1-1
	1.1 Purpose and Scope	1-1
	1.2 Relationship to Other Documents	1-1
	1.3 Revisions	1-1
2.0	DEVELOPMENT PLAN	2-1
	2.1 Summary	2-1
	2.2 Critical Development Items	2-1
	2.3 Major Milestones To Be Accomplished	2-1
	2.4 Major Milestones Already Accomplished	2-6
	2.5 Development Items	2-7
3.0	SUBSYSTEM TEST DEFINITIONS AND OBJECTIVES	3-1
	3.1 Evaluation Testing	3-1
	3.2 Supplier Acceptance Tests	3-1
	3.3 Supplier Qualification Tests	3-1
	3.4 Major Ground Tests	3-1
	3.5 Flight Operations	3-2
	3.6 Off-Limit Tests and Error Margin Analysis	3-2
4.0	INSTRUMENTATION SYSTEM DESCRIPTION	4-1
	4.1 Operational Measurements	4-1
	4.2 Operational Instrumentation	4-5
	4.3 Flight Development Instrumentation	4-9
	4.4 Special Instrumentation	4-15
	4.5 Scientific Instrumentation	4-20
5.0	DEVELOPMENT TEST PLAN	5-1
	5.1 Measurement Requirements	5-1
	5.2 Component Development and Qualification	5-11
	5.3 Quality Assurance Provision	5-12
	5.4 Acceptance Tests	5-12
	5.5 Instrumentation Pre-Installation Acceptance	5-14
	5.6 Instrumentation Calibration	5-14
	5.7 Subsystem Tests and Integrated System Tests	5-16
	5.8 Subsystem Checkout Tests	5-18
	5.9 Ground Tests	5-20



Section	Page
5.10 Analysis	5-22
5.11 Nonconformance Report	5-23
5.12 Vehicle Configuration List	5-23
5.13 The Off-Limit Test	5-24
6.0 TEST REQUIREMENTS	6-1

APPENDIXES

A.	OPERATIONAL INSTRUMENTATION COMPONENTS	A-1
B.	FLIGHT DEVELOPMENT INSTRUMENTATION COMPONENTS	B-1
C.	SPECIAL INSTRUMENTATION COMPONENTS	C-1
D.	SCIENTIFIC INSTRUMENTATION COMPONENTS	D-1



ILLUSTRATIONS

Figure		Page
1-1	Documentation Relationships	1-2
2-1	Instrumentation System Development Plan	2-2
2-2	Component Development Plan Qualification Test Schedule	2-3
4-1	Block Diagram of Communication and Instrumentation Subsystem	4-3
4-2	Typical Flight Development Instrumentation Measurements System	4-10
5-1	Instrumentation Subsystem Development Logic	5-2
5-2	Instrumentation Development Test Summary	5-5
5-3	Instrumentation Subsystem Test Summary	5-7
5-4	Instrumentation Development Test Flow	5-10
5-5	Instrumentation Pre-Installation Checkout and Control Chart	5-15
5-6	Typical Instrumentation Hardware Calibration Card and Curve	5-17
5-7	Instrumentation Process and Checkout Specification Development	5-19
5-8	Instrumentation Test Plan Spacecraft Harness Checkout and Component Installation	5-21



TABLES

Table		Page
6-1	Qualification Summary of Instrumentation Subsystems: Operational Measurement	6-3
6-2	Qualification Summary of Instrumentation Subsystems: Heat Shield Measurement	6-4
6-3	Qualification Summary of Instrumentation Subsystems: Flight Development Instrumentation Measurement	6-5
6-4	Qualification Summary of Instrumentation Subsystems: Flight Development Instrumentation	6-6



1.0 INTRODUCTION

The instrumentation subsystem development plan (SDP) provides a test program to ensure that the instrumentation equipment will perform to mission requirements. The instrumentation subsystem consists of the following components:

1. Operational instrumentation
2. Flight development instrumentation
3. NASA-furnished instrumentation (GFAE)
4. Special instrumentation
5. Scientific instrumentation.

1.1 PURPOSE AND SCOPE

The SDP defines the analysis and testing required for lunar orbital rendezvous (LOR) qualification. In addition to providing general direction for planning, provisioning, and development activities of S&ID and its sub-contractors, the SDP provides requirements for integrated subsystem tests in ground and flight test vehicles.

1.2 RELATIONSHIP TO OTHER DOCUMENTS

The SDP has been prepared in accordance with the documentation requirements of the Apollo Program Plan, SID 62-233. It supports the flight programs specified in MDS-8, Revision 3, and in the Development Test Plan (DTP), SID 64-1707, and also provides a cross-correlation of development. General flow relationships are diagrammed in Figure 1-1.

Schedules contained herein are compatible with contractual commitments of the effectivity dates shown on each schedule.

1.3 REVISIONS

To ensure that the SDP maintains its value as a directive document, it will be revised as required rather than at specified periods. Revisions by technical direction will be incorporated upon receipt of a Contract's Advice notice stating NAA's position.

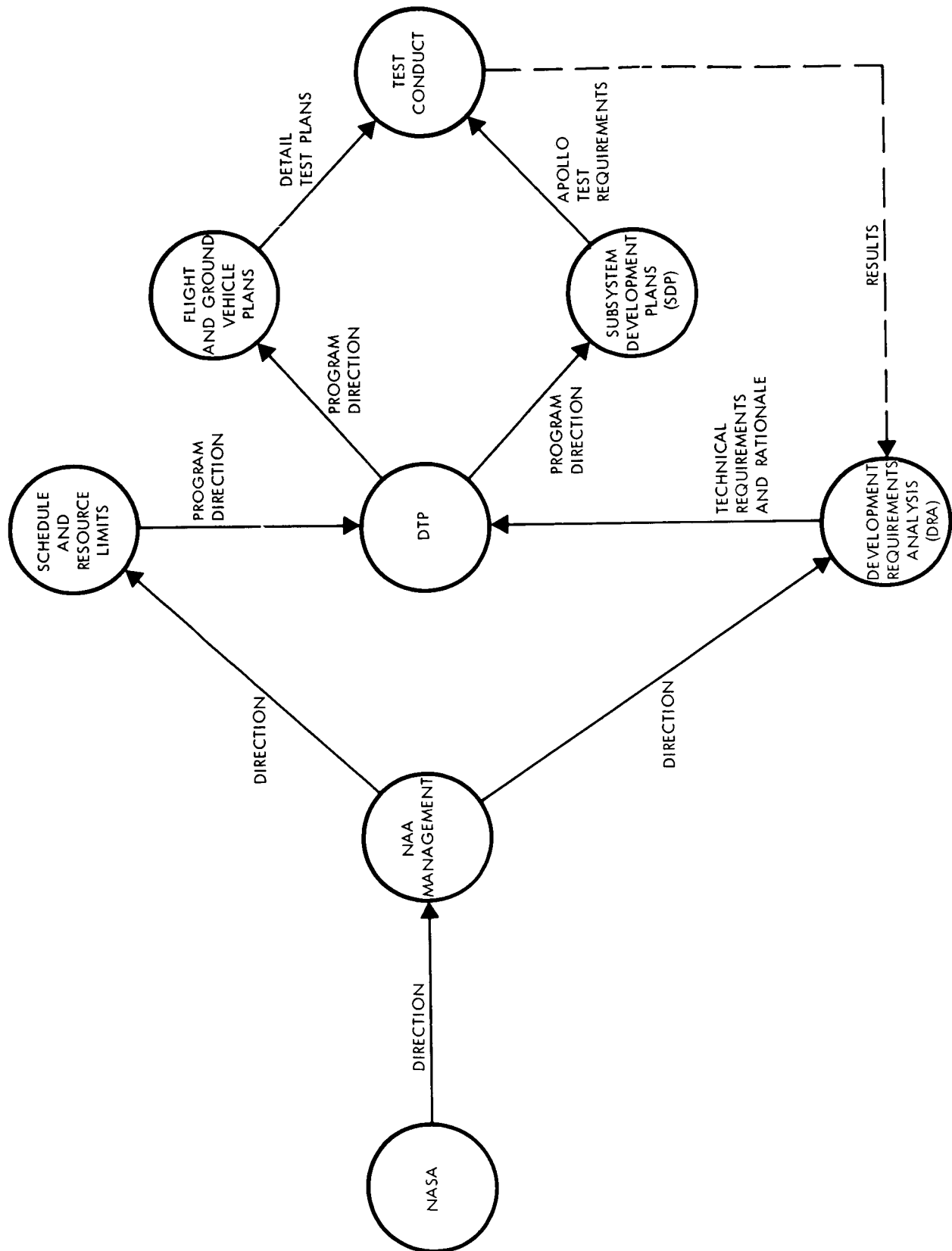


Figure 1-1. Documentation Relationships



2.0 DEVELOPMENT PLAN

2.1 SUMMARY

The instrumentation SDP delineates the system engineering efforts to be performed on each measurement as established in the measurement requirements list (MRL) for each vehicle. An analysis will be performed to determine the operational, physical, and environmental constraints associated with each measurement; and when these constraints have been established, the hardware will be selected accordingly.

After the hardware has been chosen, specifications and documentation control will be established with the selected supplier. Compliance of all hardware with the program requirements will be assured by documentation control. The status of instrumentation subsystem development is shown in Figure 2-1.

The component development test program is approximately sixty percent complete, and tests are being scheduled in support of MDS-8, Revision 3. A component qualification test schedule for operational instrumentation equipment and test levels is shown in Figure 2-2.

2.2 CRITICAL DEVELOPMENT ITEMS

The critical development items are as follows:

1. Development and verification of heat shield instrumentation to support Spacecraft 009
2. Review of instrumentation criticality and off-limit testing prior to Spacecraft 012

2.3 MAJOR MILESTONES TO BE ACCOMPLISHED

1. Establishment of operational, flight development, and R&D environment measurement requirements for Block II vehicles
2. Determination of equipment requirements for implementation of operational, flight development, and R&D environmental measurements for Block II

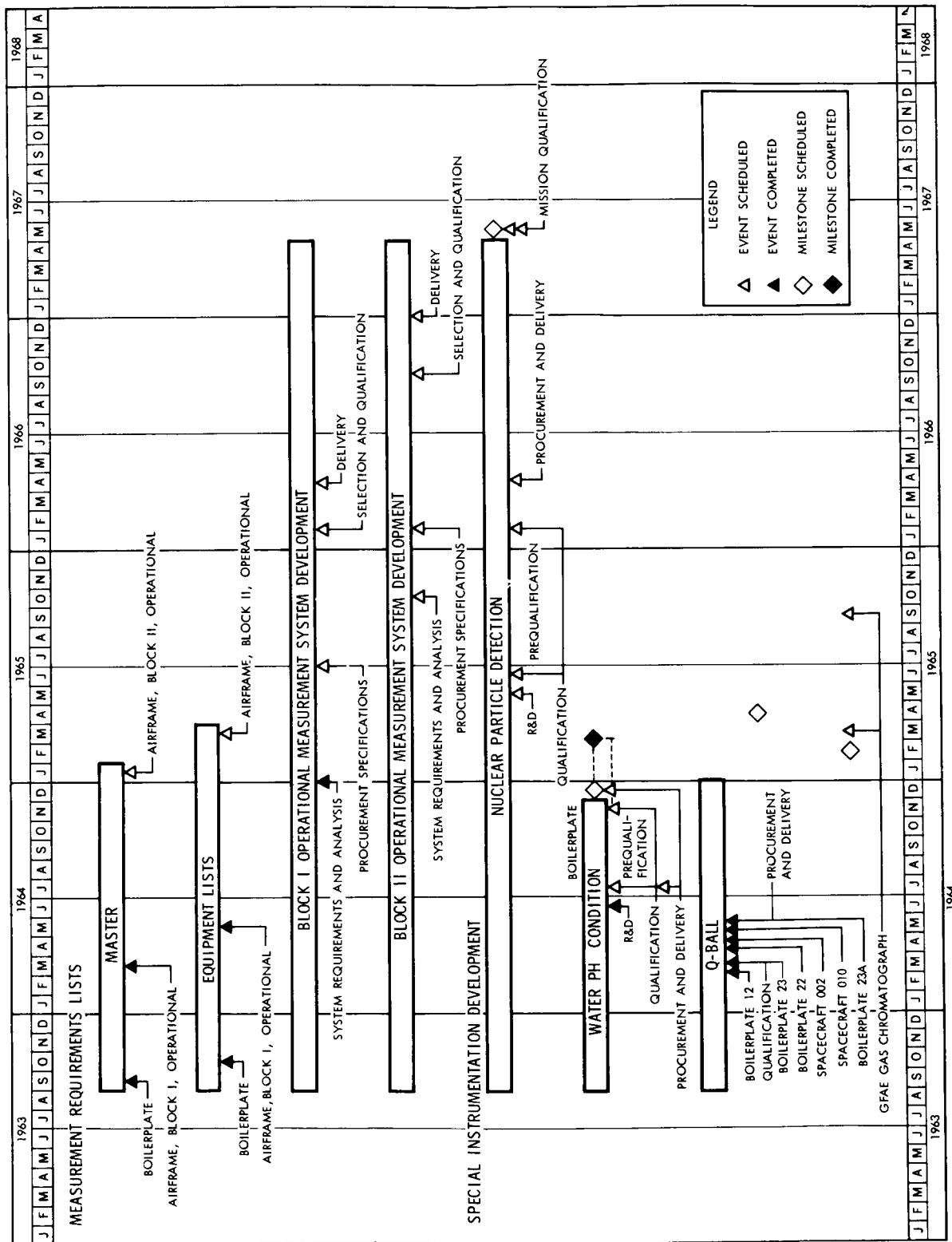
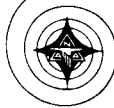


Figure 2-1. Instrumentation System Development Plan



PROCUREMENT SPECIFICATION	EQUIPMENT NOMENCLATURE	SOURCE	QUALIFICATION TEST SCHEDULE 1965						CALIBRATION MA-SPEC NO.
			6-1-64 TO 9-1-64 TO 9-1-64 TO 12-31-64						
			JAN	FEB	MAR	APR			
ME106-0015 ME411-0255 ME473-0036	MC901-0112 VIBRATION MEASUREMENT SUBSYSTEM VIBRATION MS ACCELEROMETER VIBRATION MS CABLE VIBRATION MS AMPLIFIER	ELECTRA-SCIENTIFIC ELECTRA-SCIENTIFIC ELECTRA-SCIENTIFIC	C B A C B A C B A					0304-0022 NOT REQD 0304-0022	
ME161-0015 ME265-0007 ME361-0004 ME361-0006 ME361-0007 ME361-0008 ME901-0338	MC431-0022 TEMPERATURE MEASUREMENT SUBSYSTEM TEMP MS ZONE BOX & CABLE ASSEMBLY TEMP MS T/C & PLUG ASSEMBLY TEMP MS T/C TEMP MS T/C TEMP MS T/C TEMP MS T/C TEMP MS SIG COND	SPACE SCIENCE, INC. SPACE SCIENCE, INC. SPACE SCIENCE, INC. SPACE SCIENCE, INC. SPACE SCIENCE, INC. SPACE SCIENCE, INC. SPACE SCIENCE, INC.	A A A A A A A					0204-0108 NOT REQD NOT REQD NOT REQD NOT REQD NOT REQD NOT REQD 0204-0108	
ME181-0076 ME431-0037 ME431-0038 ME473-0060	MC901-493 DIFFERENTIAL TEMPERATURE SUBSYSTEM DIFF TEMP SYS AMPL & POWER SUPP DIFF TEMP SYS SENSOR-PROBE DIFF TEMP SYS SENSOR-SURFACE DIFF TEMP SYS RACK ASSEMBLY	ROSEMOUNT ROSEMOUNT ROSEMOUNT ROSEMOUNT	C C C					NOT REQD 0204-0124 0204-0124 0204-0124	
ME431-0024 ME901-0339	MC431-0024 ABLATION MEASUREMENT SUBSYSTEM ABLATION SENSOR ABLATION SIG COND	AVCO AVCO	C B A C B A					0204-0097 0204-0097	
ME431-0026 ME901-0332	MC431-0026 CHAR MEASUREMENT SUBSYSTEM CHAR SENSOR CHAR SIG COND	THERMA-TEST THERMA-TEST	C B A C B A					0204-0120 0204-0120	
ME431-0043	GAS VELOCITY SENSOR	FLOW TECHNOLOGY				C B A A		TBD	
ME432-0082 ME432-0096	MC432-0082 RESISTANCE TEMPERATURE SUBSYSTEM RESIST. TEMP SENSOR SURFACE RESIST. TEMP SENSOR PROBE (CLOSED)	TEMTECH TEMTECH	C A C A					0204-0109 0204-0109	
			CLASSES OF EQUIPMENT A - MANNED FLIGHT VEHICLE INSTRUMENTATION B - UNMANNED FLIGHT VEHICLE INSTRUMENTATION C - STATIC FIRING OR GROUND TESTS INSTRUMENTATION						

Figure 2-2. Component Development Plan Qualification Test Schedule (Sheet 1 of 3)



PROCUREMENT SPECIFICATION	EQUIPMENT NOMENCLATURE	SOURCE	QUALIFICATION TEST SCHEDULE 1965					CALIBRATION MA-SPEC NO.
			6-1-64 TO 9-1-64	9-1-64 TO 12-31-64	JAN	FEB	MAR	APR
ME432-0088	MC432-0088 SURFACE HEAT FLUX MEASUREMENT SUBSYSTEM CALORIMETER, SENSOR ASSEMBLY	HIGH TEMP, INC.		A				NOT REQD.
ME432-0089	MC901-0114 STRESS MEASUREMENT SUBSYSTEM STRESS MS STRAIN GAGE	MICRODOT	C B A					NOT REQD
ME432-0090	STRESS MS STRAIN GAGE	MICRODOT	C B A					NOT REQD
ME432-0091	STRESS MS STRAIN GAGE	MICRODOT	C B A					NOT REQD
ME901-0320	STRESS MS SIG COND	MICRODOT	C B A					0204-0107
ME432-0103	PROPellant FLOWMETER	RAMAPO	C B A					0204-0111
ME449-0005	MC449-0005 STANDARD PRESSURE SUBSYSTEM PRESSURE TRANSDUCER	MICRO SYSTEMS, INC.	C B A					0204-0104
ME449-0051	PRESSURE TRANSDUCER	MICRO SYSTEMS, INC.	C B A					0204-0104
ME449-0052	PRESSURE TRANSDUCER	MICRO SYSTEMS, INC.	C B A					0204-0102
ME449-0053	PRESSURE TRANSDUCER	MICRO SYSTEMS, INC.	C B A					0204-0103
ME449-0054	PRESSURE TRANSDUCER	WIANCKO	C B A					0204-0105
ME449-0055	PRESSURE TRANSDUCER	MICRO SYSTEMS, INC.	C B A					0204-0104
ME901-0288	PRESSURE SIG COND	MICRO SYSTEMS, INC.	C B A					0204-0102
ME901-0289	PRESSURE SIG COND	MICRO SYSTEMS, INC.	C B A					0204-0102
ME449-0015	MC449-0015 MASS FLOW SUBSYSTEM MASS FLOW TRANSDUCER	ROSEMOUNT	C					0204-0100
ME449-0020	MC449-0020 LINEAR ACCELEROMETER SUBSYSTEM LINEAR ACCELEROMETER	STRATHAM	C B A					0304-0023
ME449-0091	LINEAR ACCELEROMETER	PALOMAR	C B A					0304-0023
ME449-0029	MC449-0021 STANDARD TEMPERATURE SUBSYSTEM TEMP TRANSDUCER	MICRO SYSTEMS, INC.	C B A					0204-0098
ME449-0030	TEMP TRANSDUCER	MICRO SYSTEMS, INC.	C B A					0204-0112
ME449-0032	TEMP TRANSDUCER	MICRO SYSTEMS, INC.	C B A					0204-0114
ME449-0034	TEMP TRANSDUCER	MICRO SYSTEMS, INC.	C B A					0204-0117
ME449-0040	TEMP TRANSDUCER	MICRO SYSTEMS, INC.	C B A					NOT REQD
ME449-0041	TEMP TRANSDUCER	MICRO SYSTEMS, INC.	C B A					0204-0113
ME449-0050	TEMP TRANSDUCER	MICRO SYSTEMS, INC.	C B A					0204-0116
ME449-0097	TEMP TRANSDUCER	MICRO SYSTEMS, INC.	C B A					TBD
ME901-0290	TEMP SIG COND	MICRO SYSTEMS, INC.	C B A					0204-0116
ME901-0291	TEMP SIG COND	MICRO SYSTEMS, INC.	C B A					0204-0116
CLASSES OF EQUIPMENT A - MAINTAINED FLIGHT INSTRUMENTATION B - UNMANNED FLIGHT VEHICLE INSTRUMENTATION C - STATIC FIRING OR GROUND TESTS INSTRUMENTATION								

Figure 2-2. Component Development Plan Qualification Test Schedule (Sheet 2 of 3)



PROCUREMENT SPECIFICATION	EQUIPMENT NOMENCLATURE	SOURCE	QUALIFICATION TEST SCHEDULE 1965										CALIBRATION MA-SPEC NO.
			6-1-64 TO 9-1-64	9-1-64 TO 12-31-64	JAN	FEB	MAR	APR	MAY	JUN			
ME181-0115 ME449-0065 ME901-0581	MC449-0065 FLOWMETER SUBSYSTEM FLOWMETER RACK ASSEMBLY FLOWMETER SENSOR FLOWMETER SIG COND	TYLAN TYLAN TYLAN		C C									NOT REQD 0204-0123 0204-0123
ME449-0064	MC449-0064 THERMAL FLUX SYBSYSTEM THERMAL FLUX TRANSDUCER	HY-CAL		A									NOT REQD
ME449-0066	ABS PRESS. TRANSDUCER	SOLID STATE INSTR		ACCEPTANCE TEST ONLY									0204-0129
ME449-0067	DIFF PRESS. TRANS MED RANGE			ACCEPTANCE TEST ONLY									0204-0128
ME449-0070	ABS PRESS. TRANS LOW RANGE	SOLID STATE		ACCEPTANCE TEST ONLY									0204-0129
ME478-0053	DIFF PRESS. TRANSMITTER			ACCEPTANCE TEST ONLY									0204-0130
ME449-0090	FLOW TRANS VENTURI	SOLID STATE							C				TBD
ME464-0090	POWER SUPPLY (4 CHANNEL)	BALDWIN-LIMA-HAMILTON		A									NOT REQD
ME470-0100	EVENT SEQUENCER	KEARFOIT		A									NOT REQD
901-0080	MC901-0080 ACOUSTIC MEASUREMENT SUBSYSTEM ACOUSTIC	LING-TEMCO-VOUGHT							C B A				0304-0027
901-0254	SIGNAL COND ASSEMBLY	HOOVER		ACCEPTANCE TEST ONLY									0203-0145
ME901-0479	MC901-0479 SIGNAL CONDITIONER SIG COND. STRAIN GAGE	BALDWIN-LIMA-HAMILTON										C	0204-0106
CLASSES OF EQUIPMENT A - MANNED FLIGHT VEHICLE INSTRUMENTATION B - UNMANNED FLIGHT VEHICLE INSTRUMENTATION C - STATIC FIRING OR GROUND TESTS INSTRUMENTATION													

Figure 2-2. Component Development Plan Qualification Test Schedule (Sheet 3 of 3)



3. Establishment of procurement specifications for new requirements for Spacecraft 017 and 020, and Block II spacecraft
4. Preparation and release of instrumentation drawings for planned Blocks I and II spacecraft
5. Development and qualification of special instrumentation that exceeds the present state-of-the-art, For example:
 - a. Nuclear particle detection system
 - b. LO_2 and LH_2 mass flow
 - c. Heat shield thermometric measurement system.

2.4 MAJOR MILESTONES ALREADY ACCOMPLISHED

1. Official measurement lists for all vehicles through Block I except Spacecraft 017 and 020 have been released and are in the process of maintenance.
2. A preliminary measurement list effective for Spacecraft 017 and 020 has been prepared. Completion of the official list is scheduled for release in April 1965.
3. A measurement list for House Spacecraft 3 (2H-1) has been issued to instrumentation for implementation; official release was in January 1965. This is the first list for Block II and covers operational measurements only.
4. Release of equipment lists for all boilerplate vehicles and spacecraft except Spacecraft 017 and 020 has been completed. Preliminary equipment lists are in existence for Spacecraft 017 and 020 and final release will be accomplished in May 1965.
5. Procurement specifications have been released for Block I vehicles, with the exception of new requirements for Spacecraft 017 and 020.
6. All basic electrical instrumentation drawings have been released for Block I, with the exception of flight development drawings for Spacecraft 017 and 020, scientific drawings on Spacecraft 014, and R&D environmental drawings on Spacecraft 008.
7. All basic mechanical instrumentation drawings except those for Spacecraft 012, 014, 017, and 020 have been released for Block I.



8. A preliminary measurement list for 2-TV1 has been issued; official release copies will be available in April 1965.
9. A preliminary measurement list for flight development measurements has been completed for SC 101 and is undergoing technical review.

2.5 DEVELOPMENT ITEMS

2.5.1 Criticality Classification of Instrumentation Components

As a development item, all instrumentation components procured by NAA and those delivered as integral parts of subcontractors' subsystems will be reviewed for failure modes critical to crew safety. If a critical failure mode is identified, the components will be reclassified and will undergo off-limit testing.

2.5.2 Subcontractor Instrumentation

Qualification criteria and methods of qualification testing for the instrumentation of delivered subsystems by subcontractors will be received for program adequacy.

2.5.3 Heat Shield Instrumentation

2.5.3.1 Heat Shield Installation Integrity Testing

Heat shield instrumentation installation design is to be tested to ensure that no functional degradation occurs to the heat shield as a result of instrumentation sensor installation. A test plan is in preparation as an S&ID document (SID 65-243) and is scheduled for release in April 1965.

2.5.3.2 Heat Shield Instrumentation System Error Margin Analysis Test

Tests are scheduled to be performed on each heat shield instrumentation component in a simulated reentry environment, and all component operations will be monitored and recorded. To determine the system error margin, an analysis will be made using an existing computer program. A test plan is in preparation as an S&ID document and is scheduled for release in May 1965.

2.5.4 Installation Design

1. Determination of improved materials and techniques for high-temperature sleeving will be made.
2. Improved techniques for replacing and installing connectors on small instrumentation cables are being investigated.



3. The feasibility of using higher gage wire over smaller gage wire without decreasing reliability will be investigated.
4. Materials suitable for potting and bonding instrumentation components to meet the environmental requirements of the lunar mission are being investigated.
5. Improved seals for pressure transducers are being investigated.
6. Properties of solders at elevated temperatures are being investigated.
7. New instrumentation installation configurations are being investigated for the effects of environment (e. g. , vibration, humidity, and temperature).
8. Torque values for instrumentation components are being investigated to determine the physical and functional parameter changes that occur during component installation.

2.5.5 Component Development

1. Development of the nuclear particle detection system is presently in progress.
2. An instrumentation-type magnetic tape recorder has been developed and is being implemented for use in the anthropomorphic dummy in the impact test program. This tape recorder has the capability of withstanding shock and impacts much greater than the normal Apollo spacecraft criteria.
3. A humidity sensor has been developed and is being implemented for use in measuring relative humidity in the astronaut suit air-flow circuit for the thermal-vacuum tests.
4. A strain-gage load link has been developed and is being implemented which will provide strain measurements on the crew restraint harness system.



3.0 SUBSYSTEM TEST DEFINITIONS AND OBJECTIVES

The overall objectives of the instrumentation development test plan are to prove design intent and mission worthiness.

3.1 EVALUATION TESTING

Equipment evaluation will be conducted to determine the suitability of instrumentation components and/or systems prior to contract award. Detail objectives will be to (1) determine specific performance criteria, and (2) select an equipment design approach.

3.2 SUPPLIER ACCEPTANCE TESTS

Instrumentation supplier acceptance tests will be conducted by suppliers and/or S&ID to contract-specified performance criteria and monitored by NAA and government quality assurance personnel. The objectives will be to (1) establish acceptance performance criteria for all delivered equipment, (2) establish calibrations on sensors and assessor hardware affecting data transfer, and (3) accumulate performance and calibration history data.

3.3 SUPPLIER QUALIFICATION TESTS

Qualification tests will be a verification of the requirements specified in the procurement specification. The objectives will be to (1) subject the components and/or systems to specified environments, (2) verify functional operation under partial environmental exposure, and (3) verify functional operation after environmental exposures.

3.4 MAJOR GROUND TESTS

Major program ground tests consist of house spacecraft, the propulsion system development program, and the thermal-vacuum test program. In each program, instrumentation equipment will be subjected to dynamic simulations of mission usage. The objectives will be to (1) verify spacecraft design and performance, (2) verify electrical and mechanical interfaces, (3) develop and refine checkout procedures and GSE usage, (4) develop and refine integrated operations with emphasis on overall data accuracy, electromagnetic interference (EMI), and integrated systems operations,



(5) provide additional instrumentation to support unanticipated problem areas, and (6) accumulate spacecraft history and evaluate the operational lifetime of the spacecraft.

3.5 FLIGHT OPERATIONS

Flight operations will consist of all flight missions prior to and including lunar operations. Instrumentation test objectives will be to verify instrumentation equipment relative to supporting the verification of spacecraft design and performance.

3.6 OFF-LIMIT TESTS AND ERROR MARGIN ANALYSIS

Off-limit tests and system margin analyses consist of a reiterative effort to identify overall system integrity and design margins.

Off-limit test objectives will be to (1) identify components and systems that may be potential critical failures, and (2) establish red-line operational levels.

Error margin analysis test objectives will be to (1) determine individual component tolerances, (2) determine cumulative system tolerances, and (3) determine overall system data utilization accuracy.



4.0 INSTRUMENTATION SYSTEM DESCRIPTION

Instrumentation system design provides for determination of the operational status, and environmental and performance parameters of various subsystems; it is capable of conditioning the sensor or transducer outputs, providing suitable signals for display, telemetry, recording, and checkout. Parameters to be monitored are those required by the crew for normal operation, abort operation, and decision-making for control of the spacecraft; also, additional parameters will be monitored to provide data to ground personnel to verify the basis for, and to participate in, major decision-making processes of the flight crew.

Each spacecraft mission in the development program differs from any other and therefore, each requires a unique instrumentation system. A block diagram of a typical instrumentation measurement-system is shown in Figure 4-1.

4.1 OPERATIONAL MEASUREMENTS

Operational measurements are defined as those measurements which are required for a routine mission, and they are divided into three categories.

4.1.1 Category I: In-Flight Management of the Spacecraft

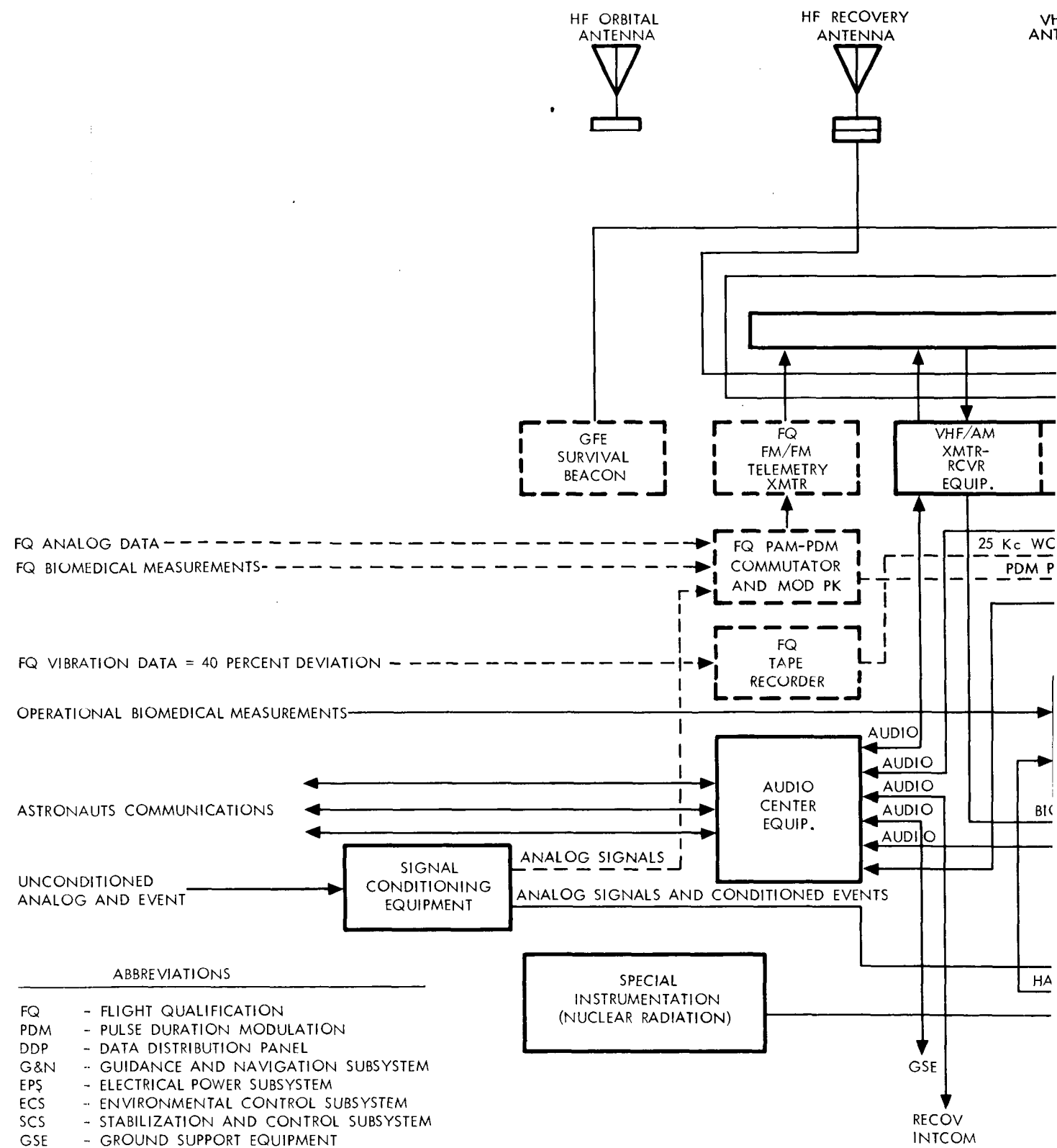
These measurements, which are essential to crew-safety, will be presented to the astronaut in real-time. They give the status parameters of spacecraft performance and indicate the proper operation sequence.

4.1.2 Category II: Mission Evaluation and System Performance

These measurements are required for ground monitoring of spacecraft performance and are either displayed at the GOSS stations or are capable of being displayed in real-time. The measurements may be used as an aid in the management of the spacecraft from the ground.

4.1.3 Category III: Preflight Checkout of the Spacecraft

These measurements are required for checkout of the spacecraft to ensure flight readiness.



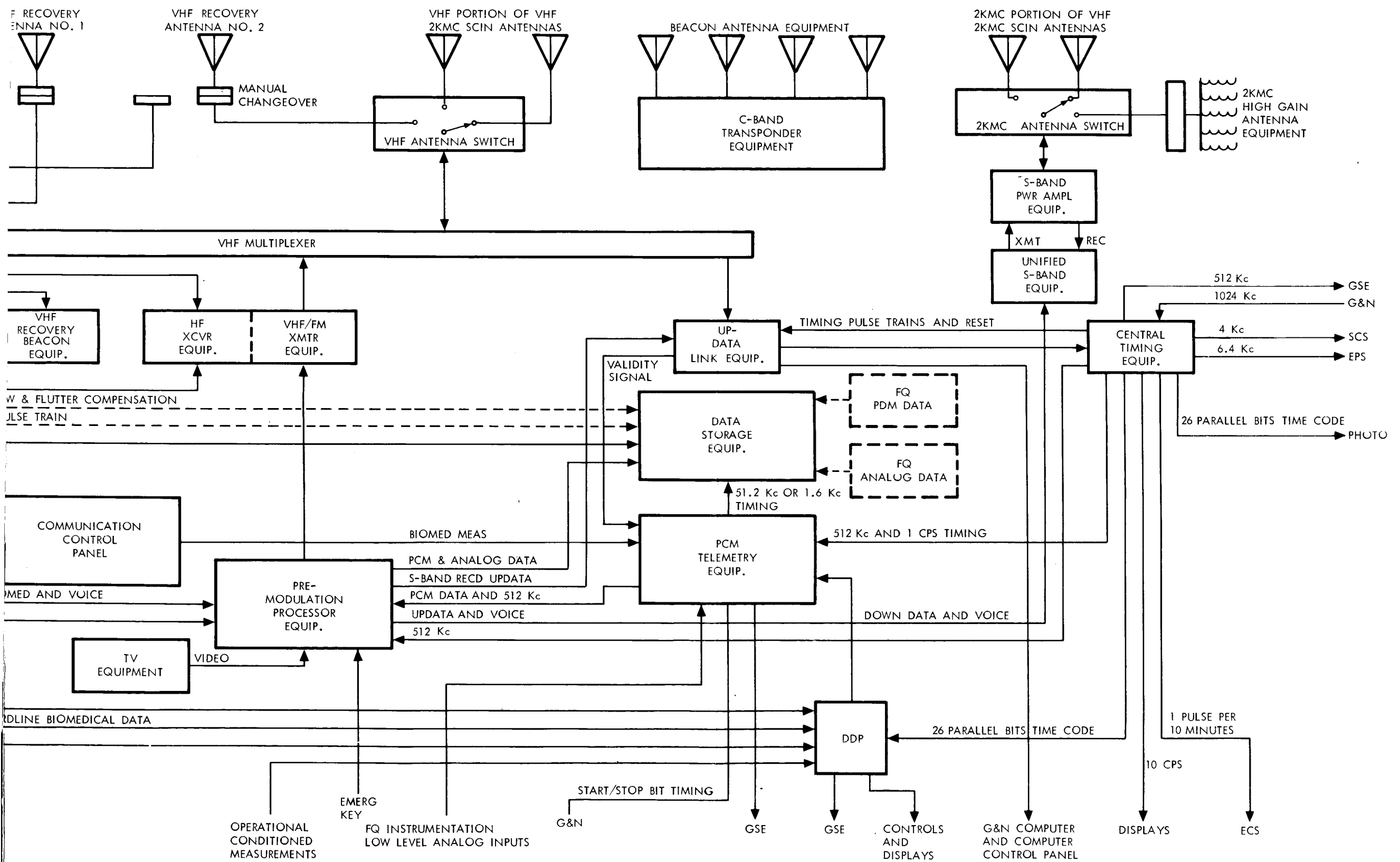


Figure 4-1. Block Diagram of Communication and Instrumentation Subsystem



4.2 OPERATIONAL INSTRUMENTATION

The operational instrumentation system is capable of making the following types of measurements:

4.2.1 Pressure

The pressure measuring subsystem will measure variations in pressure, providing an electrical signal compatible with the input requirements of the data utilization equipment. The subsystem is capable of measuring absolute, differential, or gage pressures.

4.2.2 Temperature

The temperature measuring subsystem will measure variations in temperature, providing an electrical signal compatible with the input requirements of the data utilization equipment. Physical and environmental constraints, and the temperature range to be measured determine the selection of components.

4.2.3 Flow

The flow-measuring subsystem will measure flow rate in confined lines, providing an electrical signal compatible with the input requirements of the data utilization equipment.

4.2.4 Rate

The rate-measuring subsystem will measure the rate of spacecraft attitude change. The equipment will measure yaw, roll, and pitch rates and will convert the information into electrical signals compatible with the input requirements of data utilization subsystems.

4.2.5 Quantity

The quantity-measuring subsystem will measure the quantity of a stored liquid, providing an electrical signal compatible with the input requirements of the data utilization equipment.

4.2.6 Angular Position

The angular position measuring subsystem will measure the angular position of the fuel oxidizer valves on the service propulsion engine and provide electrical signals compatible with the data utilization equipment.



4.2.7 Current

Current flow will be obtained by measuring the voltage drop across a standard millivolt shunt. This signal is conditioned to a level compatible with the data utilization equipment.

4.2.8 Event

Provisions are made to detect various types of events for real-time display and/or processing by data utilization equipment.

4.2.9 Attitude

The attitude measuring subsystem will detect and measure the roll, yaw, and pitch attitude of the spacecraft, providing electrical signals compatible with the input requirements of the data utilization equipment.

4.2.10 Voltage

Provisions are made to measure a-c and d-c voltages, providing electrical signals compatible with the input requirements of the data utilization equipment.

4.2.11 Frequency

Provisions are made to monitor inverter frequency, providing an electrical signal compatible with the input requirements of the data utilization equipment.

4.2.12 RF Power

Provisions are made to measure selected RF power levels, providing electrical signals compatible with the input requirements of the data utilization equipment.

4.2.13 Signal Conditioning Equipment

Signal conditioning equipment must be provided to electrically condition output signals from sensors and voltage buses to the proper value for transmission, recording, and/or indication by data utilization equipment. The signal conditioners will be integrated into a signal conditioning package and mounted in the command module. All necessary power supplies and electronic circuitry required for operation of each signal conditioner will be included in the package. In addition, sensor excitation power supplies of 5 and 10 vdc are provided.



The following paragraphs describe briefly the function of each type of signal conditioner.

1. D-C Bridge-Type Amplifier — A bridge-type amplifier will comprise three legs of a Wheatstone bridge circuit. The sensor will comprise the fourth leg of the circuit. This circuit is commonly used with resistance-types of temperature sensors.
2. A-C/D-C Converter — An a-c/d-c converter must rectify 115 vac 3-phase 400-cps spacecraft bus power to obtain the correct value for input to the data utilization equipment.
3. Frequency Demodulator — A frequency demodulator signal conditioner will convert the frequency of the 115-vac, 3-phase, 400-cps spacecraft power to a d-c output of the proper value for transmission, recording, and/or indication by the data utilization equipment.
4. Attenuator, D-C Active — Attenuator networks will be provided to attenuate d-c signals in the range of 7 to 50 vdc to the proper value for transmission, recording, and/or display by other data utilization equipment.
5. Attenuator Inverter, D-C Active — The attenuator inverter will attenuate and invert negative d-c signals in the range of -7 to -50 vdc to the proper value for transmission, recording, and/or indication by the data utilization equipment.
6. Phase-Sensitive Demodulator — A phase-sensitive demodulator will be used to provide a full-scale output of 0 to 5 vdc proportional to the amplitude and phase of the input signal. When the input is 180 degrees out of phase with the reference at maximum a-c rms, the output will be zero. When the input signal is in phase with the reference at maximum a-c rms input, the output will be 5 vdc. At zero input, the output will be 2.5 vdc.
7. Differential Amplifier — A differential amplifier will amplify open-ended, millivolt-level current shunt measurements to the proper d-c value for transmission, recording, and/or indication by other data utilization equipment.
8. D-C Amplifier — D-c amplifiers will be provided to amplify low-level d-c input signals of full-scale ranges of 0 to 250 mv,



0 to 700 mv, 0 to 1.4 vdc, and 0 to 7 vdc. The low-level inputs are to be transmitted as 0 to 5 vdc signals to the data utilization equipment.

9. Reference Junction — A voltage bias-type of reference junction will provide a reference voltage at a given temperature upon which thermocouple temperature readings will be referenced.

4.2.14 Data Distribution Panel

4.2.14.1 Block I Vehicles

The data distribution panels (DDP) will consist of a series of connectors to provide ground checkout access and to distribute those signals fed to the PCM telemetry to other data utilization equipment. The connectors will be packaged in two separate panels (described as an inaccessible panel and an accessible panel). The inaccessible DDP shall be mounted directly behind the accessible DDP and will become physically inaccessible once the latter is installed. The inaccessible DDP shall provide a minimum capability of 168 signal inputs and will be used to distribute signals to other data utilization equipment. The accessible DDP must be accessible to GSE and must be used for ground checkout of signals routed directly to the communications subsystem and to the inaccessible DDP, but not directly to any other utilization source. The accessible data distribution panel will have the capability to handle the following signals:

Type of Signal	Number
Analog	197
Events	116
Digital (7 at 16 bits each)	112
Spares	167
Total	<u>592</u>

No capability will be provided for stimuli insertion, patching, or for access by the crew during flight.

4.2.14.2 Block II Vehicles

4.2.15 Current Limiters

The current limiters will consist of five different models to be used in the command module and service module of the Apollo vehicles. Their



purpose will be to provide independent excitation for all the sensing and signal conditioning required for instrumentation.

4.3 FLIGHT DEVELOPMENT INSTRUMENTATION

The program requires an additional instrumentation system to obtain data of varying types on various flight tests. These tests are unique in that once the data are acquired the supporting instrumentation system configuration may not be utilized again.

Flight development instrumentation requirements are those which vary from flight to flight, depending upon mission objectives and the state of hardware development. These measurements are required to achieve vehicle test objectives relative to qualification and verification of engineering design and analysis. Requirements necessary to ensure compatibility between this instrumentation and the vehicle, such as interfaces, equipment design, and performance, are stipulated in NAA/NASA documentation. A typical flight development measuring system is shown in Figure 4-2.

The flight development instrumentation system is capable of making the following types of measurements:

4.3.1 Pressure

Generally identical to operational instrumentation (For description, refer to Paragraph 4.2.1.)

4.3.2 Temperature

Generally identical to operational instrumentation (For description, refer to Paragraph 4.2.2.)

4.3.3 Vibration

The vibration-measuring subsystem is capable of detecting and measuring the amplitude and rate of displacement in a given direction providing an electrical signal compatible with the input requirements of the data utilization equipment.

4.3.4 Current

Generally identical to operational instrumentation (For description, refer to Paragraph 4.2.7.)

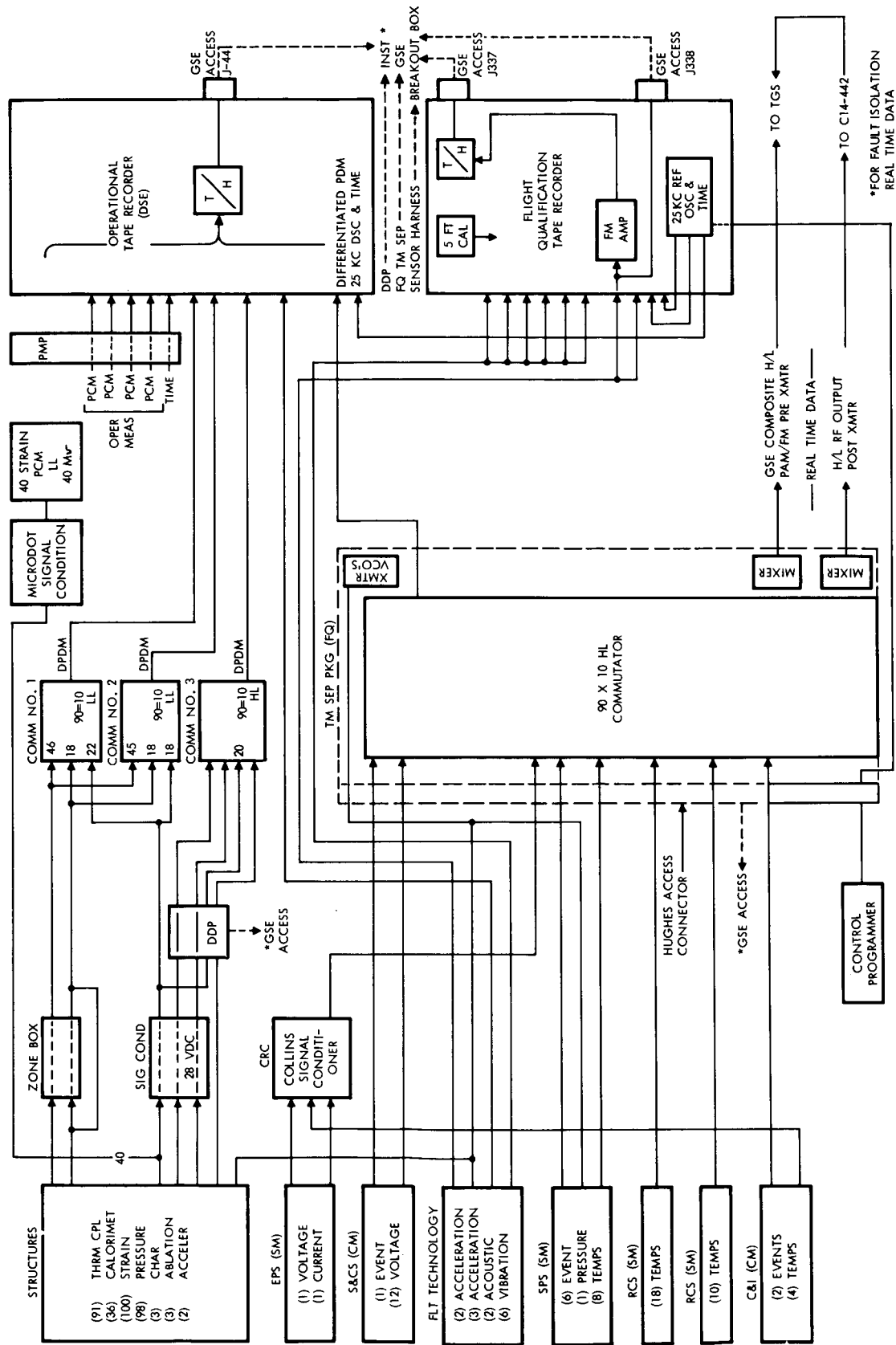


Figure 4-2. Typical Flight Development Instrumentation Measurements System



4.3.5 Strain

The strain-measuring subsystem will measure strain in designated parts of the spacecraft, e. g. , (1) command module heat shield stainless steel substructure and the aluminum inner structure; (2) service module tension bolts, beams, and outer skin; and (3) SLA sling stiffeners, cables, and outer skin. Strain gage output will be conditioned to be compatible with the input requirements of the data handling utilization equipment.

4.3.6 Acoustic

The acoustical measuring subsystem will monitor and measure the noise level in the crew compartment over the audio spectrum from 10 cps to 10 kc, in an amplitude range from 70 to 150 db. Because of the sensitivity requirement, two systems will be provided which measure noise levels from 70 to 110 db and 100 to 140 db, respectively.

4.3.7 Heat Shield Measurements

1. System Description—The objective of the heat shield measurement system is to provide data relative to reentry heating phenomena experienced by the Apollo spacecraft.
 - a. Heat Flux—The heat flux measurements will measure incident heat flux on the ablative heat shield. Capability will be provided to measure low- and high-heat flux rates.
 - (1) Low Heat Flux—A differential type calorimeter will measure heat flux on the forward and coaxial heat shields.
 - (2) High Heat Flux—A slug-type of calorimeter will measure the high heat rates associated with the aft heat shield.
 - b. Char—The depth of the char layer on the ablative heat shield will be measured by use of a series of circuits utilizing the conductive properties of charred ablator to complete the circuit. The voltage is sensed by a voltage comparator which in turn is used in a digital circuit to trigger a staircase generator. Each subsystem will consist of seven discrete measurements arranged in depth in the ablator.
 - c. Ablation—The rate of recession of the ablative heat shield surface during reentry will be measured by monitoring the decrease in emission-count rate of a radioactive isotope



embedded in the material. A series of radioactive isotopes are to be embedded at various levels in a plug, and their emission will be monitored by a Geiger Mueller tube on the back face of the heat shield substructure.

2. Implementation—In the instrumentation of an optimum design heat shield, the objective is to design and install instruments to obtain minimum perturbation of the heat shield performance. Design considerations to accomplish this include the following:
 - a. Chemical characteristics between instrument materials and heat shield at all anticipated temperatures
 - b. Differential thermal coefficients of expansion inducing mechanical stress of heat shield components during transient and steady-state conditions
 - c. Thermal characteristics of transducers relative to heat shield (including melting point, specific heat, mass, coefficient of thermal conductivity, emissivity, etc.)
 - d. Positive prevention of plasma flow through instrument and/or heat shield junction during vibration, thermal expansion cooling, and heating
 - e. Mechanical stress analysis of installation over-temperature range
 - f. Vehicle design criteria, i. e. , maximum bond line temperature, maximum back-face temperature, etc.

In the design of the transducers, the specific measurement requirement is the prime consideration, i. e. , the accuracy desired and the range of measurement. It is important that the analysis of the output signal produce only single valued results, and the instrument should be capable of providing adequate data for this analysis.

3. Current Status—The present status of this effort indicates that basic design of all instruments has been completed. Simulated reentry heating tests have been conducted to provide qualitative data with respect to functional characteristics of each instrument design.



The qualification test statuses of each of the instruments are as follows:

a. Temperature measurement system:

Thermocouple assembly - completed
Signal conditioner - completed

b. Surface recession: in progress

c. Char: in progress

d. Heat flux:

Low range sensor — completed
High range sensor — scheduled mid-January
Sequencer — in progress
Reference junction — scheduled early January

e. Pressure: completed

4. Measurement Verification Test Program — The objective of this program will be to provide an analysis of the capability of the instruments to measure the desired quantity respective to its function. It is not enough to provide a calibration of the instrument; tests must be conducted to determine the magnitude of known errors due to conductance, dissimilarities of materials, etc. The errors must be correlated to the undisturbed heat shield material in determining the actual effect of reentry heating and the heat shield material.
5. Off-Limits Tests — The heat shield instrumentation has been assigned a criticality level of 1. The off-limit tests will determine the design margins for each instrument and establish the margin of safety required to assure adequate system design. A test plan for the heat shield instrumentation is presently being formulated and will be issued during the first quarter of 1965.

4.3.8 Attitude

The attitude of the command module during boost about the aerodynamic axis will be sensed by a Q-ball. This device will be NASA/GFAE and will form the nose cone of the launch escape tower. Internally-mounted pressure transducers will furnish output signals corresponding to the dynamic pressures.



4.3.9 Flight Development Data Distribution Panel

A signal distribution panel will be provided to handle up to 90 high-level differential input signals and distribute these signals to a high level commutator in addition to providing analog data access,

4.3.10 Flight Development Data System

A flight development data system comprised of the following components will be installed in the spacecraft. This system is integrated with the spacecraft's communication subsystem.

1. Commutators — Two types of commutators will be provided as NASA/GFAE.
 - a. High-Level Commutators: 90 x 10 high-level, solid-state commutators will be provided. Each unit, with the exception of the signal sources, power source, and output loads, will be a completely integrated and operating system capable of multiplexing signals 0 to 5 vdc full-scale and providing a standard inertial rate integrating gyroscope (IRIG) waveform. Simultaneous pulse amplitude modulation (PAM), pulse duration modulation (PDM), and differentiated PDM outputs will be provided.
 - b. Low-Level Commutators: 90 x 10 low-level mechanical commutators will be provided. Each unit shall be capable of multiplexing low-level signals of the following full-scale ranges: 0 to 10 mv, 0 to 20 mv, 0 to 30 mv, 0 to 40 mv, and 0 to 60 mv — and providing a standard IRIG waveform output. The nominal pulse amplitude is to be 0 to 5 vdc full-scale. The multiplexer will have simultaneous PAM, PDM, and differentiated PDM outputs.
2. Standard Electronics Package (SEP) — One complete telemetry system comprised of components outlined below and including one 90 x 10 high-level commutator will be packaged on a chassis provided by NAA/S&ID. NASA will assemble these components and perform all necessary qualification tests pertaining to this assembled package.
 - a. FM Transmitter: One FM telemetry transmitter capable of transmitting standard IRIG channels will be used.



- b. Mixer: One telemetry mixer capable of mixing prescribed combinations of IRIG subcarrier bands 1 through 18 and A through E will be provided.
 - c. Modulation Package: A modulation package consisting of the IRIG subcarrier oscillators will be furnished.
 - d. Calibrator: A calibration network will be provided as NASA/GFAE. This network must be capable of interrupting, upon command, all subcarrier data channels with a five-point calibration over the 0 to 5 vdc range.
3. Flight Development Tape Recorder — A 14-channel tape recorder with wow and flutter compensation and timing provisions will be used.
4. Mod-Kit PAM/FM/FM Telemetry System — A complete telemetry system will be provided as NASA/GFAE for installation in the service module. NASA will assemble and perform all necessary qualification tests pertaining to this kit which will include the following components:
- a. Low-Level Commutator: One low-level mechanical commutator capable of accepting 86 differential input data channels of ranges 10, 20, 30, 40, and 60 mv and conditioning them to standard IRIG PAM, PDM, and differentiated PDM outputs of 0 to 5 vdc
 - b. Modulation Package: One modulation package consisting of 11 standard IRIG subcarrier oscillators
 - c. Mixer: An IRIG telemetry subcarrier mixer
 - d. Calibrator: A unit capable of injecting a five-point calibration
 - e. FM Transmitter: An IRIG specified unit

4.4 SPECIAL INSTRUMENTATION

Implementation of the instrumentation for anthropomorphic test dummies, analytical, fire-detection, photographic coverage, radiation monitors, and biomedical are organizationally separated as special instrumentation.

In support of design, requirements are analyzed, procurement specifications prepared, and vendor sources are selected and monitored for qualified products. A major portion of the equipment is obtained from NASA GFAE. CFE procured items are subject to NASA approval.



The following projects are presently being implemented:

1. Anthropomorphic test dummies to support water impact tests on Boilerplates 1, 2, and 28, and on Spacecraft 002A and 007 (ATR 201 and subs)
2. Biomedical instrumentation for Spacecraft 008 environmental test chamber tests
3. Fire detection system for Spacecraft 001 tests
4. Spacecraft 007 flotation test, Phase III
5. A pH water condition monitor system
6. Interface coordination and installation provision for GFAE gas chromatograph
7. GFAE cameras to provide test coverage of several test vehicles and spacecrafts
8. The operational nuclear particle detection system

4.4.1 Anthropomorphic Test System

The anthropomorphic test dummies are fully instrumented test articles used in water impact tests to determine impact acceleration and the angular rates to which the spacecraft crew is subjected, and to ascertain vehicle reentry conditions upon Earth impact. The series of tests include instrumentation consisting of 3 rate gyros, 6 linear accelerators, 11 strain gages (on the restraint harness), signal conditioners, a tape recorder, a power inverter, and battery packs.

The initial test plan and equipment are presented in a document entitled "Apollo Anthropomorphic Dummy Instrumentation System," dated May 1963.

4.4.2 Biomedical Instrumentation (Spacecraft 008)

Instrumentation will be furnished to measure the inlet temperature to the suits. The following components will comprise the suit temperature measuring system:

ME 432-0096

Sensor by Temtech



ME 901-0479

Signal Conditioner by Baldwin-Lima-Hamilton

V16-751175

Bridge Completion Network by NAA

4.4.3 Fire Detection System (Spacecraft 001)

The thermal detection system (TDS) for Spacecraft 001 consists of an electronic control unit (ME 901-0285) and a thermally sensitive sensor (ME 901-0284). The sensor is a semiconductor cable, the dielectric between the conductors changing its resistance as a function of ambient temperature.

The purpose of the TDS is to detect overheating on each of the reaction control system panels and around the service propulsion system. It has been procured, delivered, and installed in Spacecraft 001. One unit was procured for in-house testing. Process Specification MA 0203-0159 defines the procedure to be used in the tests.

4.4.4 pH Water Condition Monitor

The purpose of the pH water condition monitor is to monitor continuously the pH value of the water produced in the Apollo fuel cells. The pH value of the water is an indication of the operational efficiency of the fuel cells and also a determination of the potability of the water. An increase in the pH of the water beyond a predetermined level will indicate a malfunction in the operation of the fuel cell. The selected instrument is a commercially procured, glass electrode monitor with a flowing junction reference electrode utilizing KCl as the electrolyte. Details of the monitor are specified in the following documents:

NAA/S&ID Specification MC 432-0100, Monitor, Water Condition, pH

NAA/S&ID Specification Control Drawing ME 432-0100, Monitor, Water Condition, pH

Beckman Proposal No. CS 64-542A, A pH Monitor System

4.4.5 Gas Chromatograph

The GFAE gas chromatograph is a gas analyzer with the capability of quantizing the primary compounds and elements (H_2 , N_2 , O_2 , H_2O , NH_3 , and CO_2), and determining the quantity of trace contaminants present, to a detectable limit of 5 ppm.



NAA supporting efforts are directed toward providing interface coordination and installation capabilities in the spacecraft. The interface is controlled by an ICD No. MH01-03104-116, approved by NAA on 3 December 1964, and transmitted to NASA for its concurrence.

The supplier is qualifying the analyzer to NASA requirements, and NASA has the prime responsibility for checkout calibration and maintenance procedures. NAA will participate in the monitoring of the qualification tests.

NAA is currently preparing the installation procedure for the spacecrafts with vehicle effectivities on Spacecraft 008, 011, 012, 014, 015, 017, and 020.

NAA will conduct brief calibration checks on each spacecraft instrument and will also conduct extensive integrated systems tests on the prototype model by April 1965.

4.4.6 Camera Systems

Apollo development photographic instrumentation consists primarily of GFAE cameras (cine) and associated equipment installed in or on the boilerplate and spacecraft vehicles to record (on film) events that occur during the flight on the vehicle. Resultant data are applicable to the total determination of the in-flight performance of various vehicle systems with regard to accomplishing mission objectives.

Abort test vehicles—Boilerplates 23, 22, and 23A—each have three complete camera systems on-board. A system consists of camera and lens, protective case where required, timing pulse generator, control unit, battery power supply, and interconnecting electrical cables.

Apollo impact test vehicles—Boilerplates 1, 2 and 28—have on-board camera system installations as part of the instrumentation to obtain data during the vehicle land and water impact tests. These camera systems vary from the abort vehicle type of systems in that a lighting system is required and a more sophisticated timing system is used. The three on-board, high-speed cameras view the anthropomorphic dummies and record their reactions during vehicle impact. The data are an aid in the evaluation of the performance of the crew restraint systems and crew couch shock attenuation systems. Three exterior (on-site) cameras are used for recording vehicle positioning and attitude during the landing impacts.

Spacecraft 011 has a two-camera recording system on-board to monitor the main display console panel. Installation includes a lighting system in addition to the other camera system components. Qualification testing of the lighting system will be conducted by NAA,



4.4.7 Nuclear Particle Detection System

1. System Description—The nuclear particle detection system (NPDS) measures the nuclear environmental external to the spacecraft. Specifically, the NPDS, which is located behind a thin aluminum diaphragm in the service module fairing area, detects the quantity of protons and alphas in several energy ranges. The signals generated are telemetered in real-time to the ground. The information will be used at the MSFC to compute radiation depth doses, a complete mission radiation profile, and missile redirection, if required.
2. Implementation—NASA direction to proceed with the design and procurement of the NPDS was given in December 1963, following a year's study of the nuclear environment and a complete survey of state-of-the-art of space radiation instrumentation. A breadboard was constructed which provided the analysis of the design parameters for specification and evaluation purposes. Procurement Specification MC 431-0040 and SCD ME 431-0040 were prepared in July 1964. After receipt and evaluation of proposals a supplier was selected and procurement initiated.
3. Current Status—A contract was awarded the Philco Western Development Laboratory in November 1964 for design and production of the NPDS.
Phase I—including design, hardware/development, production, and delivery of engineering models will be complete by 15 June 1965.
Phase II—fabrication of qualification models and qualification testing—is scheduled for completion by 15 December 1965.
Phase III—production of flight hardware—will proceed concurrently with the qualification testing when delivery of the first hardware is made in February 1966.
4. Test Program—A test program will be established by the supplier, for development, qualification, and acceptance testing. The NPDS has been assigned a criticality level of 3, and four models will be subjected to qualification testing. All production models will be acceptance-tested and given a nuclear calibration at the source. Engineering, qualification, and production model testing will be monitored and evaluated by NAA. The NPDS will be installed in the house spacecraft for integrated systems tests and combined electromagnetic interference (EMI) testing. Pre-installation acceptance (PIA) testing will be performed on production stock and spaces at appropriate locations. Flight qualification will be accomplished on Spacecraft 017 and 020.



5. Effectivity— The NPDS will be installed on all Block II vehicles.

4.5 SCIENTIFIC INSTRUMENTATION

GFAE instrumentation provides for measurements to be made in flight by the astronauts. The equipment consists of biomedical sensors, signal conditioners, and data-recording and operational equipment to monitor physiological behaviour, scientific experiments, and technological equipment in order to study effects under zero-gravity and vacuum environment and further man's knowledge of extraterrestrial space.

Since the equipment will be NASA GFAE, interface coordination, installation provisions, and integrated systems testing will be an NAA implementation effort. Scientific equipment interfaces will be documented in the form of ICD's. Developmental test plans include close liaison between NASA and the various experimenters. The spacecraft flight qualification requirements are being imposed upon all equipment to be supplied by the experimenters under NASA cognizance. Equipment test plans will be formulated jointly with the respective experimenters and integrated into the overall NAA integrated systems test. Performance and Interface (P&I) Specifications, SID 62-1002 and SID 64-1388, cover the interface requirements.

Documents to be furnished by NASA and the experimenters for NAA review and concurrence will include (1) PIA procedures, (2) experimenter qualification test program, (3) failure analysis, (4) specification documentation, and (5) functional test plans.

Operational camera systems are defined as part of the vehicle scientific payload. The cameras will be used for (1) synoptic terrain photography, (2) airglow horizon photography, (3) ultraviolet astronomical observations, and (4) meteorological observations. The effectivity extends to Spacecraft 014 and subsequent manned orbital flights. Cameras (cine) will also be used on Spacecraft 104, 105, 106, 107, and 108 to photograph lunar excursion module docking exercises during Apollo orbital flights.

Currently being developed is a photographic instrumentation system (GFAE) which will be available for operation in a space environment. Camera and lens will each have the capability of being purged, pressurized with an inert gas, and sealed. The first hardware of this type will be installed on Boilerplate 22 to record in-flight data at extreme altitudes (200,000 feet). Subsequent units are scheduled for installation on Spacecraft 002, 010, and 011.



5.0 DEVELOPMENT TEST PLAN

The test plan purpose is to prove the design and flight worthiness of each subsystem to and beyond the specified limits of functional and environmental stresses by means of ground simulation of critical mission requirements. Programs, schedules, and environmental criteria are delineated for all Apollo spacecraft subsystems and associated ground support equipment. The individual qualification of each subsystem is planned by first defining the scope of each test program, then delineating the tests to be performed with the hardware required, and finally establishing minimum test criteria consistent with equipment criticality. The ground qualification test program culminates in the operational integration of all subsystems to assure dimensional and functional compatibility under mission environment.

The objective of the test plan is to present the philosophy to be employed to verify the capabilities of S&ID-designed Apollo spacecraft subsystems and associated GSE to accomplish the intended mission. Qualification will be achieved by demonstrating the capability of the systems to perform within specified requirements and by showing that function performance and quality provision can be repeated on randomly selected test articles. The program will show a step by step qualification plan from one level of assembly to the next and from one mission phase to the next. Qualification for each preliminary step in the flight will be achieved just before the effected vehicle launch date. (Ultimate qualification for the lunar mission requirements will be achieved prior to the launch date.)

The Apollo instrumentation subsystem development plan includes analysis, design, and development of the subsystem; liaison between NASA and the subcontractors; supervision of manufacturing and assembly; approval of required documentation; establishment of a program of tests and test support; and data analysis for system performance and reliability. A development plan logic chart is shown in Figure 5-1.

5.1 MEASUREMENT REQUIREMENTS

Analysis will be made to determine if measurement requirements are in agreement with program and test objectives. Each vehicle instrumentation requirement will be critically screened to ensure fulfillment of objectives, elimination of excessive items, and practical system implementation.

Each measurement requirement will be studied for optimum implementation within constraints of criticality, reliability, cost, schedules, and performance.

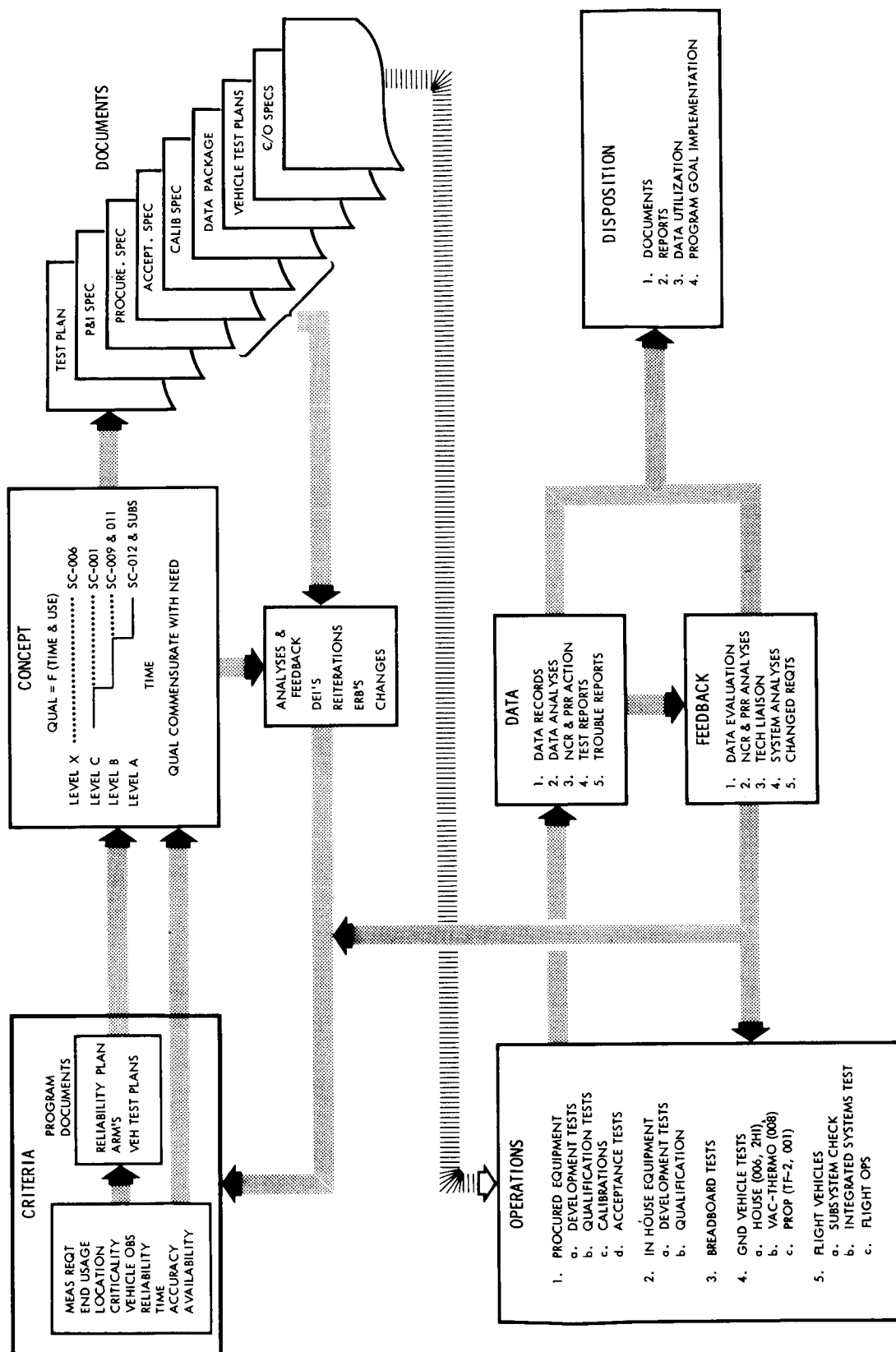


Figure 5-1. Instrumentation Subsystem Development Logic



After measurement requirements are defined, existing hardware will be examined for use. Where hardware does not exist, detailed specifications will be established and released to appropriate suppliers for bid. Supplier responses will be evaluated, and the best source will be selected for procurement. Compliance of all equipment with the stringent requirements of the program will be assured by procuring all items under specification control documentation.

5.1.1 Evaluation Tests

To determine their adequacy for usage on Apollo, evaluation tests will be conducted on instrumentation systems procured from various suppliers. These tests will be conducted under critical environments simulating those to be encountered in the Apollo program. The results of these tests will be a factor in the determination of the procurement source for each type of transducer.

5.1.2 Development Tests

Because some parameters cannot be measured practically by existing instrumentation techniques, a program will be initiated to develop new instrumentation techniques and equipment. This program will involve new design concepts and intensive laboratory testing under simulated conditions representative of operational usage.

5.1.3 Qualification Tests

Qualification tests will be performed on the fully developed subsystem and components to ensure compliance with instrumentation subsystem and spacecraft requirements. Tests will be performed on a sample of each type of component, with the samples to be produced using the same tooling and processes and under the same conditions as those intended for vehicle use. Each component will be subjected to qualification tests in accordance with criteria established by S&ID. Three qualification categories or phases will be established:

1. Fully qualified for manned lunar mission
2. Qualified for earth-orbital unmanned flights
3. Qualified for limited noncritical use, such as static firings, acoustic vibration, integrated environmental tests, and other ground tests.

Successful completion of the qualification tests for each phase will automatically qualify the component to that level of usage.



5.1.4 Reliability Tests

Reliability tests and statistical analysis will be performed, as required, to ensure that the subsystem and components will meet the reliability requirements of the Apollo program. Operating and test histories of the contractor, subcontractors, associate contractors, and NASA will be compiled and used in reliability analysis. Failure mode and effects analysis will be performed for each flight vehicle.

5.1.5 Quality Assurance Tests

A quality assurance program will be implemented to verify, by means of inspection and testing, that the components comprising each measuring system actually perform as required. The program will assure that the manufacturing techniques employed and the materials selected will result in a high-quality product to meet the design requirements.

5.1.6 Compatibility Tests

Subsystems will be assembled and operated under all modes of the mission profile to assure compatibility of the equipment with other spacecraft systems. The subsystems will be installed in a geometric mock-up of the spacecraft.

5.1.7 Configuration Control

Upon determination of the components in the measurement system, an equipment list will be completed providing the information necessary to initiate wiring and vehicle installation design. The installation design will be the engineering control document specifying vehicle effectivity, equipment location, and operating process specifications. Procurement will normally be scheduled so that delivery is to the manufacturing site for vehicle assembly. Particularly fragile or sensitive units will be delivered to out-of-station installation areas.

5.1.8 Development Test Program

An instrumentation development test summary is shown in Figure 5-2. The items to be tested include sensors, associated signal conditioning equipment, measurement subsystems, and special instrumentation such as optical, scientific, and biomedical.

5.1.9 Development Test Criteria

The initial phase of the development plan is to determine measurement system performance criteria. The criteria will be determined from existing



	DEVELOPMENT TEST COMPONENTS TEST	DEVELOPMENT TEST ASSEMBLY	DEVELOPMENT TEST SUBSYSTEM	QUALIFICATION TEST	ACCEPTANCE TEST	PIA LOGISTICS SPARES	CALIBRATION AND/OR FUNCTIONAL CHECKOUT	GROUND VEHICLE	HOUSE VEHICLE	FLIGHT VEHICLE
OPERATIONAL SUBSYSTEM										
PRESSURE	X		X	X	X	X		X	X	X
TEMPERATURE	X		X	X	X	X		X	X	X
FLOW	X		X	X	X	X		X	X	X
ACCELERATION	X		X	X	X	X		X	X	X
QUANTITY	X		X	X	X	X		X	X	X
POSITION	X		X	X	X	X		X	X	X
ATTITUDE	X		X	X	X	X		X	X	X
SIGNAL CONDITION	X	X	X	X	X	X		X	X	X
POWER SUPPLY	X	X	X	X	X	X		X	X	X
R&D SUBSYSTEM										
PAM F/M F/M T/M	X	X	X	X	X	X	X		X	X
COMMUTATOR	X	X	X	X	X	X			X	X
POWER SUPPLY	X	X	X	X	X	X			X	X
SENSOR	X	X	X	X	X	X			X	X
SIGNAL CONDITION	X	X	X	X	X	X			X	X
CAMERA	X	X	X	X	X	X			X	X
SPECIAL SUBSYSTEM										
NUCLEAR PARTICLE DETECTION	X	X	X	X	X	X			X	X
GAS CHROMATOGRAPH	X		X	X	X				X	
PH METER	X		X	X	X				X	

Figure 5-2. Instrumentation Development Test Summary



program documentation, customer direction, contract ground rules, and experience applicable to the subsystem program. Factors to be considered are measurement requirements, environmental conditions, vehicle test objectives, reliability, program schedule, equipment, and data accuracy.

5.1.10 Subsystem Concept

Based on determination of these criteria, a period of system analysis is utilized to derive a subsystem conceptually and to delineate system utilization. For the Apollo program the subsystem components must be of a quality capable of reliable and safe data acquisition for long-term space missions. Secondly, it was determined that the instrumentation subsystem and components would be required throughout the total duration of the Apollo program, starting with ground test vehicles, proceeding to unmanned flight vehicles, and culminating with manned lunar landing vehicles. Based on these criteria, a qualification level was established which would be commensurate with the worst-case need and would be broken down into three phases: (1) for manned flight vehicle operation, (2) for unmanned flight vehicle operation, and (3) for ground test vehicles, such as static firings, engineering test and house vehicles. This category would vary according to specific vehicle applications. An instrumentation subsystem test summary is shown in Figure 5-3.

1. Classification - The instrumentation equipment will be classified to the degree or extent of reliability requirements, based on criticality and/or class of equipment as follows:
 - a. Class A: manned flight vehicle instrumentation
 - b. Class B: unmanned flight vehicle instrumentation
 - c. Class C: static firing or ground test instrumentation, which may vary between vehicles, depending on specific vehicle application
2. Criticality of Equipment - The instrumentation equipment criticality levels will be as follows:
 - a. Criticality 1: Components having any mode of failure which could cause loss of crew, or which could endanger ground personnel, or which could cause conflict with range safety requirements
 - b. Criticality 2: Components having any mode of failure which could cause mission abort

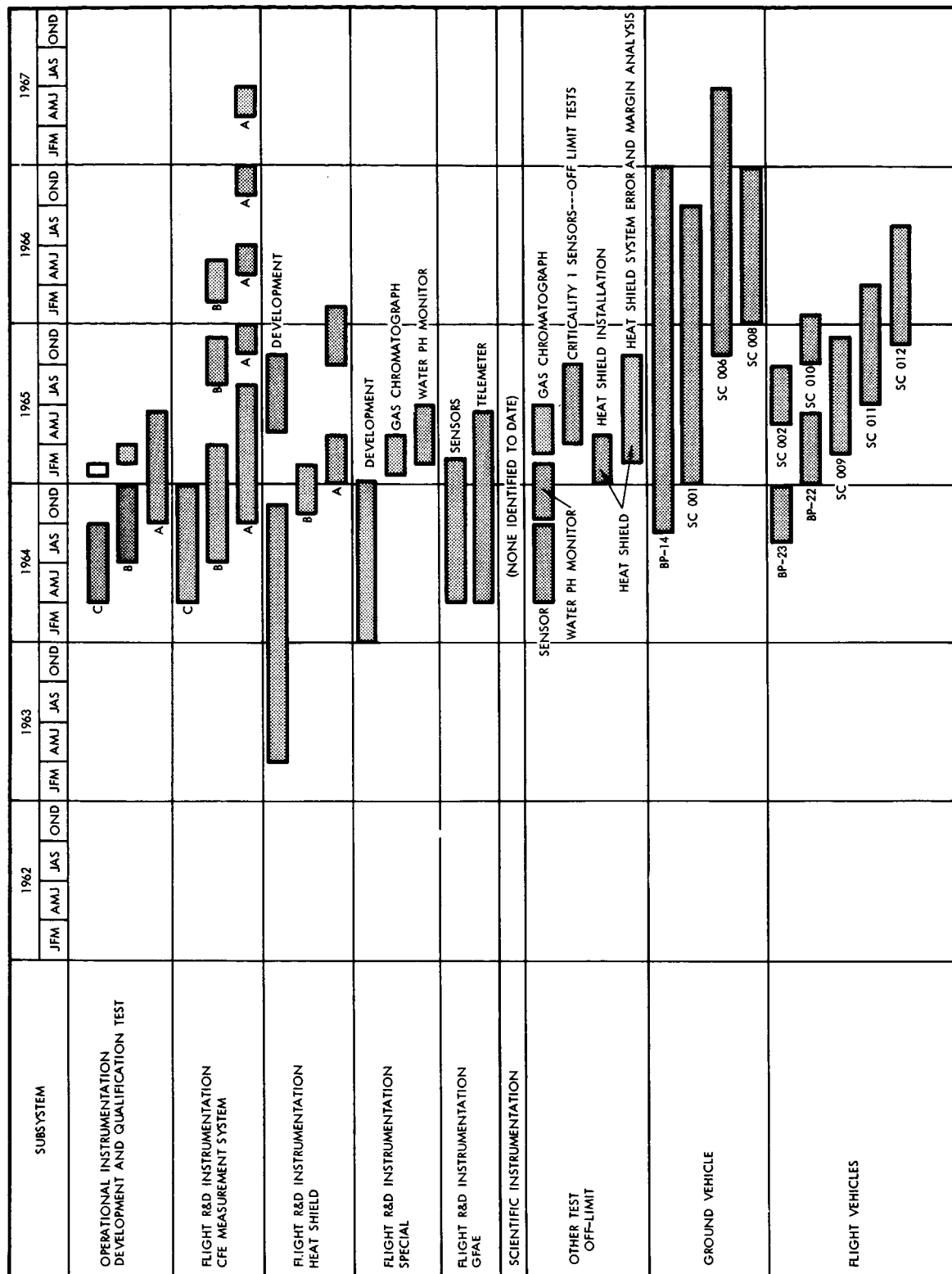


Figure 5-3. Instrumentation Subsystem Test Summary



c. Criticality 3: Components having modes of failure which may cause lesser incidents

3. Qualification Tests - Qualification tests will be in accordance with the methods and levels specified in Specification MC 999-0050, MC 999-0051. Specific procurement documents may supplement or amend these values.

Unless otherwise specified, qualification tests will consist of those tests listed herewith. With proper justification, applicable portions of the required qualification tests may be waived in accordance with MC 999-0050, paragraphs entitled "Waiver of Tests" and "Test Waiver Request."

Qualification test specimens must have been successfully subjected to the required acceptance tests before the start of qualification testing.

Qualification test specimens, whenever feasible, are to be operated and monitored during, as well as after, each environment.

Qualification Testing Sequence

Test	Class of Equipment			Test Specimens No. 1, No. 2, No. 3
Electromagnetic interference	A	B	C	Note: The test sequence is to be determined by the specific procurement document. There will be a minimum of two test specimens for Criticality 3 Instrumentation and a minimum of three test specimens for Criticalities 1 and 2 Instrumentation.
Vibration	A	B	C	
Acoustics	A	B	C	
High and low temperature	A	B	C	
Humidity*	A	B	C	
Acceleration	A	B		
Mechanical shock	A	B		
Gaseous oxidizer	A			
Oxygen (4 hours at 14.7 psi)*	A			
Vacuum - temperature	A			
Propellant compatibility	A			
Leakage	A			
Salt fog*	A			

Following the determination of a qualification test level, a review will be initiated on existent hardware and on developments in the industrial community. Procurement documents will be initiated delineating the design performance, qualification, and equipment test requirements. These documents are to be released to potential suppliers for competitive bidding and technical response. (The responses will be evaluated on the basis of technical merit and capability of providing the desired equipment.) Concurrently,

*For manned flight command module (crew compartment), the humidity, oxygen, and salt fog tests must be a sequential, combined test (corrosive contaminants, oxygen, and humidity).



technical analysis will be initiated to refine the criteria, review the usage, and re-define the development testing by a process of reiteration.

This effort will be considered a basic milestone in that primary analysis of requirements will have been completed and a decision for equipment implementation made. In some cases, pre-contract tests would be conducted for evaluation between competitive responses or to proof proposed technical applications.

5. 1. 11 Engineering Component Tests

The selected equipment suppliers will be required to conduct a series of tests to provide adequate documented assurance that the end item will meet its specified performance requirements. The test plan will be reviewed and will include a series of tests to qualify the item to the level of usage through a series of tests generally consisting of the following: (1) engineering prototype testing, (2) manufacturing production model testing, (3) functional acceptance testing, and (4) calibration and qualification testing. The testing at the supplier will be monitored by quality assurance and engineering personnel from NAA to provide assurance of proper performance. From this point, the equipment will be delivered to NAA for calibration, installation, and checkout operations. Functional tests will be performed on instrumentation components when the equipment is received and calibrated. Additional verification will be obtained in the ground operations and checkout operations to further assure that the equipment will be of proper design and of satisfactory quality. Thereupon, the equipment will be installed and operated as an integral subsystem, independently at first and concurrently with other vehicle systems later. Data will be accumulated at all operation levels and performance will be analyzed to further determine the suitability of the equipment.

5. 1. 12 Vehicle Flight Tests

The flight operations will provide performance data to determine the suitability of equipment operation for subsequent flight use.

5. 1. 13 Analysis and Feedback

Information obtained from the equipment supplier and from both ground and flight operations will be accumulated and will consist of performance records, nonconformance reports, trouble reports, test reports, and data evaluation. These data will be evaluated in conjunction with a continuing overall system analysis which will define marginal and off-limit operations. The system and performance analysis will indicate marginal areas of initial applications. Where such areas are identified, improvements will be initiated on the marginal components, and off-limit testing will be conducted to further qualify the initial usage equipment. A basic flow diagram is shown in Figure 5-4.

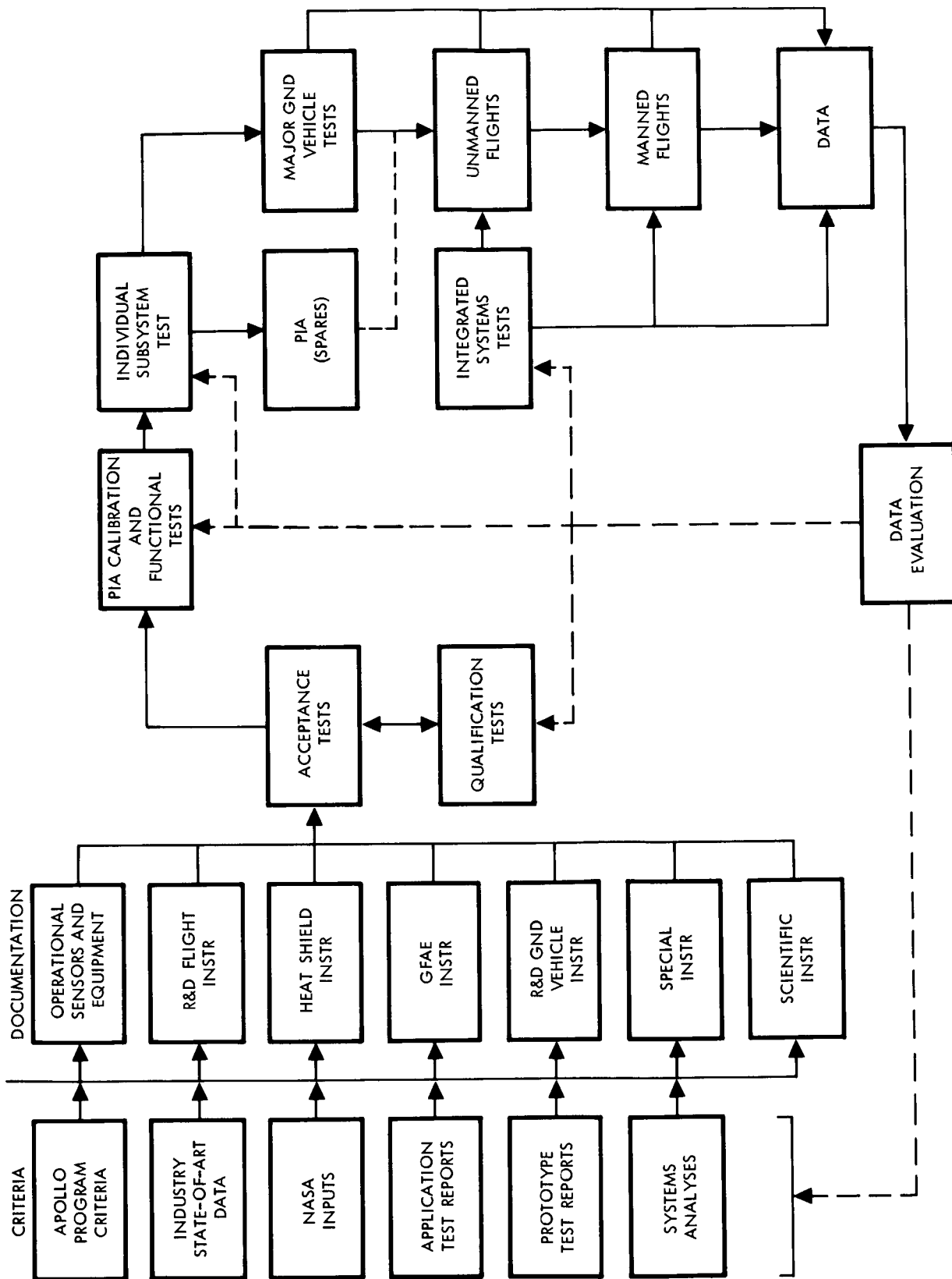


Figure 5-4. Instrumentation Development Test Flow



5.2 COMPONENT DEVELOPMENT AND QUALIFICATION

5.2.1 Objective

The objective of qualification tests will be to ensure that the system components provided by the suppliers will perform according to the specifications, under defined environmental conditions, and with sustained reliability over a specified period of time.

The various system components will be tested for performance characteristics, such as linearity, hysteresis, stability, repeatability, and output level. During the tests, the components will be subjected to varying environmental conditions of vibration, shock, acceleration, acoustics, temperature, and radiation. Reliability will be determined by monitoring component output over an extended period of operation.

5.2.2 Program Requirements

Test articles will include such components as pressure transducers, temperature transducers, flow meters, quantity transducers, acoustic transducers, vibration accelerometers, attitude gyros, rate gyros, signal conditioners, and ablation transducers. Data will be recorded by oscillographs, oscilloscope cameras, tape recorders, and other data-logging devices.

5.2.3 Equipment

Vacuum chambers, pressure chambers, ovens, etc., will be used to simulate the desired environmental conditions for test.

5.2.4 Facilities

The test facility will consist of a complete evaluation laboratory equipped with environmental chambers, measurement standards, recording equipment, and typical test equipment.

5.2.5 Test Schedules

Test schedules will vary for each component, depending upon type, the number of each type being tested, and the test vehicle for which it is intended.



5.3 QUALITY ASSURANCE PROVISION

5.3.1 Quality Assurance Program

The supplier is to have or establish a quality assurance program that conforms to the requirements of specification MQ0802-001.

5.3.2 Test Program

Unless otherwise specified, the supplier must establish a test program for development, qualification, and acceptance testing in accordance with Specification MC 999-0050, to the extent required by the specific procurement documents.

5.3.3 Identification and Traceability

The identification and traceability will be in accordance with the requirements of Specification MA 0201-0209 for Criticalities 1 and 2. The level of identification and traceability will be as defined in the specific procurement documents.

5.3.4 Classification of Tests

The tests specified herein will be classified as (1) qualification tests and (2) acceptance tests.

5.3.5 Testing Requirements

The supplier is to conduct all tests specified herein, unless the specific procurement documents indicate otherwise.

5.4 ACCEPTANCE TESTS

5.4.1 Objective

The objective of the acceptance tests will be to ensure that each component item received is in satisfactory operating condition and is capable of performance in accordance with the specifications.

5.4.2 Test Plan

Each component item received will be inspected initially to ensure good mechanical condition, correct dimensions, proper identification marking, etc. Following the receiving inspection, the individual component item will be subjected to an operational checkout that tests the performance characteristics of the item under limited environmental conditions indicated for the



qualifying inspection. The pre-installation test will be performed as required to support the manufacturing need date for system installation in a test vehicle. The pre-installation test will be essentially the same as the operational checkout. It will be performed to ensure that no degradation in performance has occurred during the shelftime period of the component item.

5.4.3 Examination of Product

Each unit will be examined to determine compliance with the applicable specification with respect to material, workmanship, finish, dimensions, construction, identification, and markings.

5.4.4 Vibration Test

Units will be subjected to vibration tests as specified in the applicable procurement document.

5.4.5 Insulation Resistance Test

Insulation resistance between electrically insulated circuit terminals and the mounting case will be measured. Insulation resistance should not be less than the value required by the specific procurement documents.

5.4.6 DC Resistance Test

By use of a resistance bridge or equivalent, resistance of circuit elements will be measured. DC resistance must not deviate beyond tolerance limits required by the applicable procurement documents.

5.4.7 Functional Test

Unless otherwise specified, functional tests will be performed at room ambient conditions. Tests will utilize applicable test equipment and stimuli to verify the performance requirements of the applicable procurement documents.

5.4.8 Test Conditions

Unless otherwise specified, all test facilities shall be in accordance with Standard MIL-STD-810.

5.4.9 Test Facilities

Test facilities or agencies employed for conducting the tests described herein must be approved by NAA/S&ID.



5.4.10 Operation of Test Specimen

Unless otherwise specified, all tests are to be performed with equipment mounted in a manner reasonably simulating spacecraft installation and with equipment operating as specified. Operation will be monitored during qualification tests. The installation is to be in accordance with data provided on the specific procurement documents for each component.

5.5 INSTRUMENTATION PRE-INSTALLATION ACCEPTANCE

The operation for sensors which require calibration will consist of conducting tests in accordance with applicable NAA process specifications to provide calibration verification. The data are to be compared with the latest calibration data for the unit under test to determine unit acceptability. An established acceptance tolerance referenced to the latest calibration must be adhered to. Equipment support for this operation will be scheduled with local laboratory support facilities. A pre-installation checkout and control chart is shown in Figure 5-5.

5.5.1 GFAE Communication and Signal-Conditioning Commutator Equipment

These items will be subjected to an operational performance check in accordance with applicable NAA process specifications to provide, in part, a basic check of the unit under test.

5.5.2 Invalidation

Unless otherwise specified in the instrumentation plan of action, an elapsed time of 120 days, after the initial calibration or previous PIA check on a spare item, will invalidate that item for spacecraft use. The item must be recycled through PIA to validate it again for use.

5.6 INSTRUMENTATION CALIBRATION

The calibration will be performed in accordance with process specifications generated by Instrumentation Engineering and certified by NAA inspection personnel. When a hardware item is calibrated, data will be recorded directly on a calibration card in addition to being recorded on the normal data sheet. The equipment transfer form will be filled out with processing information, and the operations will be verified by Quality Control personnel. The calibration laboratory personnel will return the calibration form with all other data to the instrumentation stockroom, along with the component. Detailed instructions delineating the manner in which the card is to be filled out will be contained in the applicable calibration process specification. Calibration data will be forwarded to the responsible

Figure 5-5. Instrumentation Pre-Installation Checkout and Control Chart



instrumentation vehicle engineer for his approval; if he approves the data, it will be forwarded to the Test Data Group for processing and distribution. For a typical instrumentation calibration card and curve see Figure 5-6.

To aid in establishing traceability and calibration history and in obtaining component malfunction analysis, a history record of each component will be maintained.

Major subcontractors and vendors will supply baseline calibration and traceability data as required by the applicable documents which delineate end-item documentation requirements for the Apollo program.

5.7 SUBSYSTEM TESTS AND INTEGRATED SYSTEM TESTS

5.7.1 Test Program

Subsystem and integrated system tests will be conducted on boilerplates and spacecrafts, either during or after completion of the manufacturing phase. Input and output readings will be made at the appropriate check points to ensure that all instrumentation components in the system are functioning according to the design specifications. Malfunctions will be investigated thoroughly, and appropriate corrective action will be determined and implemented.

Subsystem tests on Boilerplate 14 to determine the compatibility of the components with other spacecraft subsystems will be performed under operational conditions without simulated environment. The effects of vibration environment will be determined during subsystem tests conducted on Test Fixture 2 and Spacecraft 001. The effects of acoustical environment will be determined during subsystem tests conducted on Spacecraft 001. The effects of temperature and vacuum environments will be determined during subsystem tests conducted on Spacecraft 008.

5.7.2 Subsystem Tests

The objective of subsystem tests will be to determine the interaction of the individual components when they are functioning as a part of the complete subsystem.

5.7.3 Integrated System Tests

The objective of integrated system tests will be to determine the interaction of subsystem when all subsystems are functioning as a complete system.



MEASUREMENT LIST NO. _____ CODE _____ VEH. _____ CODE _____ DATE X / X / X
M D Y

a MEAS. INPUT XXXX ENGR UNITS MEASUREMENT _____

b DC VOLTS OUTPUT XX MV OR VOLTS SOURCE ME XXXXX-XXX RANGE XX TO XX

c _____ CALIB NO. .XXXX S/N XX

d _____ CONVERTER _____

e _____ 1ST CALIB ☒ RECALIB ☐ S/N _____

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80

a	x	x	x	x	x	x	x	x	x	x	
b	x	x	x	x	x	x	x	x	x	x	
c											
d											
e											

CALIBRATION
DATA CARD
FORM L21453

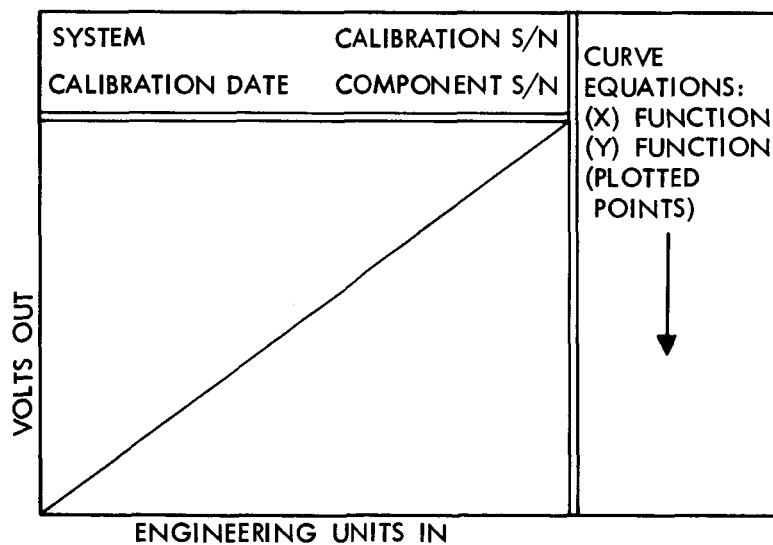


Figure 5-6. Typical Instrumentation Hardware Calibration Card and Curve



5.8 SUBSYSTEM CHECKOUT TESTS

Subsystem checkout tests will be conducted in accordance with the process specification, Apollo Spacecraft Instrumentation Checkout Requirements, and applicable spacecraft subsystems checkout procedures. An instrumentation process and checkout specification development chart is shown in Figure 5-7.

Checkout of spacecraft instrumentation subsystems will involve end-to-end subsystems response. Verification of operational measurement data will be obtained as pulse coded modulation (PCM) telemetry data and will be based on the results of an analysis of the digital print-out data via the acceptance checkout equipment (ACE) interleaver to the telemetry ground station. Verification of measurement data recorded on the flight development and operational on-board tape recorders will be based on the results of an analysis of reduced playback data. Tape reduction will be a support function of telemetry ground stations and of the Test Data Group.

The following criteria will establish configuration for checkout:

1. Type of sensor
2. Location of sensor
3. Method of stimulation
4. Equipment to be utilized in checkout
5. Approach and equipment for trouble isolation

Checkout of spacecraft measurements will require ambient on-scale and/or physically applied dynamic stimulation to data source where possible. Minimal checkout will consist of resistance and continuity checks. Recordings of sensor response at a known static ambient condition comparable to a point on the systems calibration curve will be acceptable if the overall system end-to-end data is within an established tolerance of the reference calibration point. Unless otherwise specified, sensors which indicate off-scale ambient readings throughout spacecraft power-on tests will be physically stimulated when possible.

In the event that the complete spacecraft assembly consisting of the command module service module, launch escape tower, and heat shield assemblies are not available during the Downey (S&ID) spacecraft preparation tests, simulated measurement loads and applicable read-out voltages developed across these loads may be introduced at the appropriate interfaces.

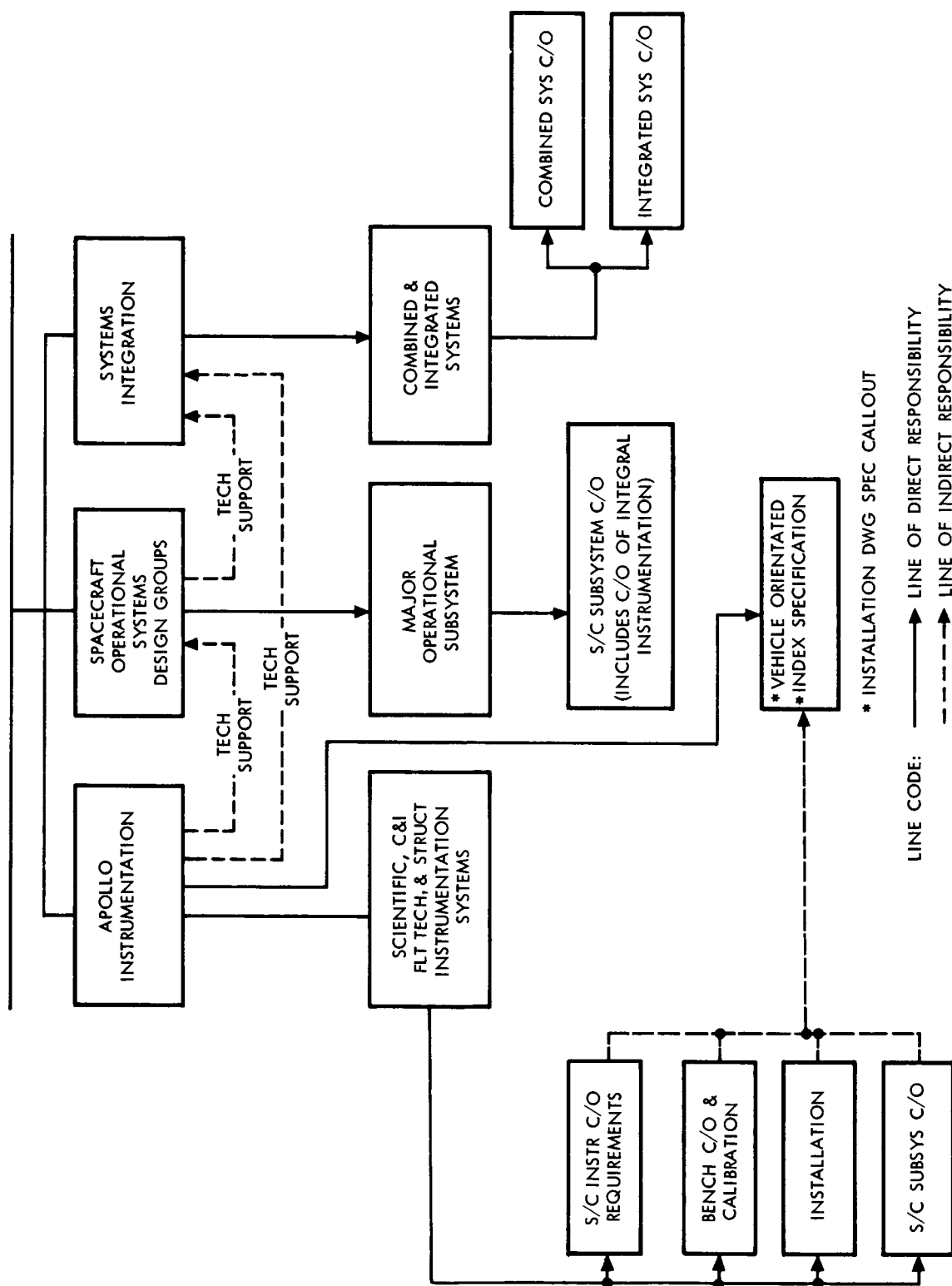


Figure 5-7. Instrumentation Process and Checkout Specification Development



When fault isolation is required as a result of quick-look data analysis, the current testing schedule will be reviewed by the responsible NAA and NASA test conductor(s) to determine the appropriate test phase in which to perform fault isolation. Instrumentation carry-on harnesses routed to an instrumentation break-out box will be provided to support fault isolation performance. Meter room equipment will be used to monitor functions available at break-out box test points. All power-on fault isolation performed will utilize special T-type, in-line access harnesses to provide normal spacecraft power and control functions to the subsystem under test. Where applicable, spacecraft fault-isolation should be categorized as resistance and continuity checks only. An instrumentation test plan for spacecraft harness checkout and component installation is shown in Figure 5-8.

5.9 GROUND TESTS

The individual ground qualification of instrumentation equipment and subsystems will be in accordance with the established minimum tests criteria consistent with equipment criticality as stipulated in Apollo spacecraft system specification SID 63-313 and CS7 Technical Specification—Block II, SID 64-1344.

The Boilerplate 14 configuration will support early unmanned flight vehicles, and most operational measurements will be included in the measurements list. However, those which are passive or will not yield useful data have been deleted. The flight development electronic equipment will be installed when Boilerplate 14 is re-configured to Spacecraft 009. The flight development measurements will not be included in the list. Those measurements of this nature which will be required for support of systems test operations will be added to the vehicle and controlled by Apollo Test Requests.

The ground test vehicles are utilized to test components for spacecraft system compatibility prior to utilization on flight vehicles. This concept allows utilization of pre-qualified and/or lower-qualified instrumentation. Analysis of data between tests establishes the functional capability of the instrumentation for the next test. Should any systems compatibility problems exist, they can be defined and resolved by this method. Boilerplate 14 and Spacecraft 006 furnish a tool for simulating system flight performance.

The effects of thermal vacuum effect on instrumentation systems performance of a simulated lunar flight will be evaluated on Spacecraft 008.

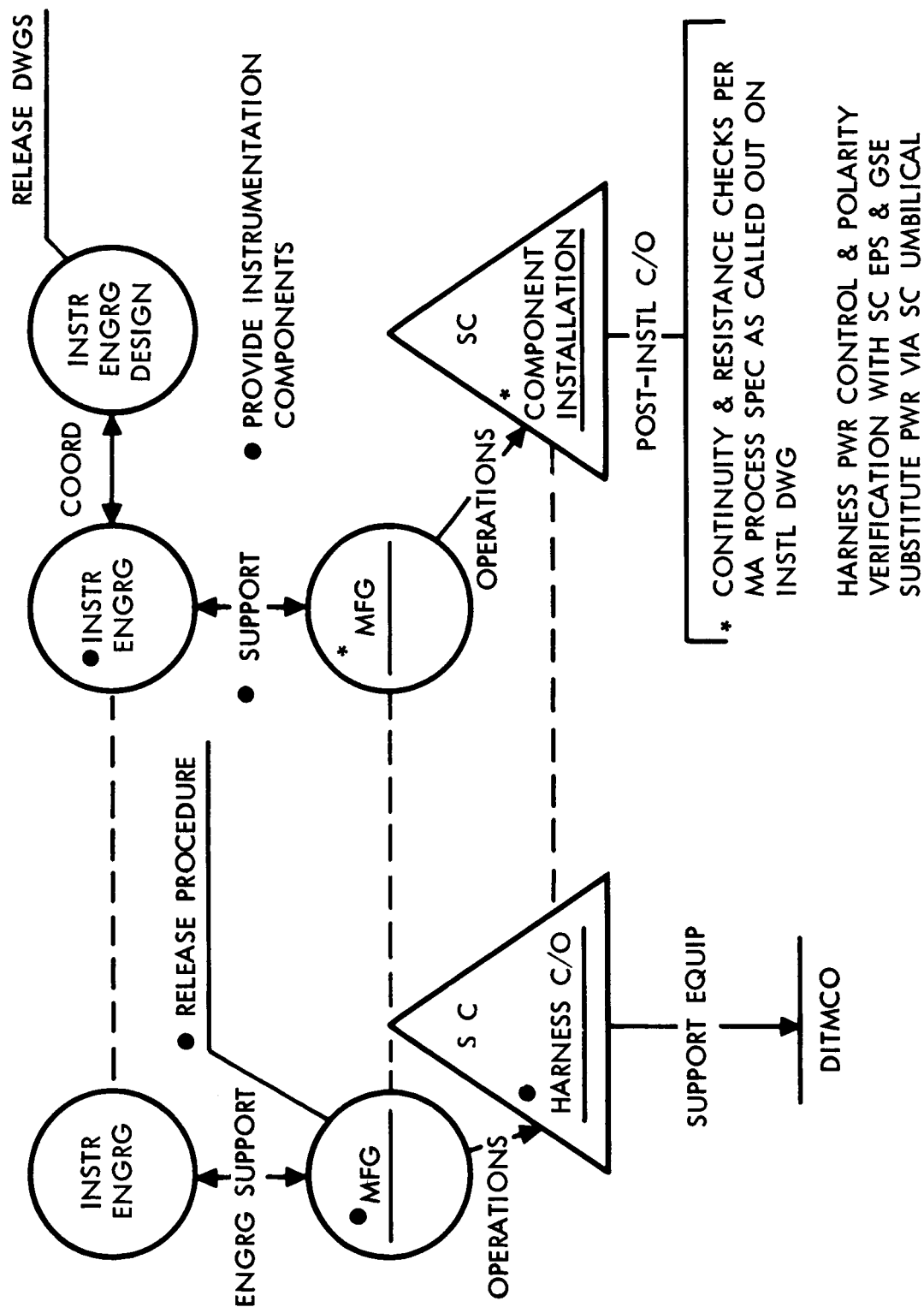


Figure 5-8. Instrumentation Test Plan Spacecraft Harness Checkout and Component Installation



5. 10 ANALYSIS

To maintain program visibility and to provide a definition of the overall development activities in relationship to the instrumentation development plan, the following basic support documents are presented:

1. The Apollo CSM Manufacturing Operations Requirements Plan (MORP) documents define the engineering requirements for the assembly and subsystem test processes, prior to system checkout as described in the Ground Operation Requirements Plan (GORP). A table cross-referencing document numbers against vehicles, will be included in an early revision.
2. The Apollo CSM Ground Operation Requirements Plan (GORP) documents present the overall engineering requirements for ground operations, from factory through launch and post-recovery testing, as required on each vehicle. A table cross-referencing document numbers against vehicles will be included in an early revision.
3. The Apollo Ground Operations Support Plan (GOSP) documents define scheduled and unscheduled maintenance and associated support requirements for each vehicle and related ground support equipment (GSE) during performance of specific test and checkout sequence (TACOS). A table cross-referencing document numbers against vehicles will be included in an early revision.
4. Functional integrated system schematics provide complete overall vehicle/support equipment interface. These drawings describe the functional system requirements for each separate vehicle in Block I and Block II. A table cross-referencing schematic drawing numbers against specific vehicles will be included in an early revision.

5. 10. 1 Pre-Flight

Functional checkout, component calibration, and subsystem test data will be employed to determine the integrity of the instrumentation components and system.

5. 10. 2 Post-Flight

Post-flight analyses will be accomplished to verify that the components and the system performed according to design requirements and to determine the system accuracy by evaluating all systems variables.



5.10.3 Component

Analysis of a component is made to establish its compatibility with its physical environment and to determine its accuracy.

The integrity of the instrumentation subsystem and of the items making up the subsystem are verified through implementing the development test plan.

The incapability of the subsystem to be put to the ultimate use calls for correction. The correction can take several paths, and each case has to be decided upon its own merits. The test requirements may be found to exceed the subsystem needs and a relaxation of test requirements may be in order. This situation will call for revision of the test plan and/or specification. Suspected problems in the conducting of tests can be verified through repetition in testing or by built-in checks since series of tests overlap to a certain extent. Problems analyzed as deficiencies in manufacturing traceable to quality control or to inadequate design will require appropriate changes and either an abbreviated test program to conform with the subsystem development test plan or a complete battery of tests to verify compliance. Corrections which reference original measurement requirements could result in the relaxation of criteria which, in some cases, would call for no new design or testing or they could lead to the organization of new parameters calling for new measurements, equipment, design, test plans, and documentation. Cases could arise which dictate complete revision of the subsystem even to the removal of certain portions thereof. Such changes should be considered only when they will not impair the mission objectives of the spacecraft and the subsystem as a whole.

5.11 NONCONFORMANCE REPORT

If a hardware item is replaced on a vehicle because of damage, a condition of out-of-calibration, return to supplier for modification, etc., the part will be sent on an NCR to Material Review where disposition will be made with Instrumentation Engineering's concurrence. The part will then be routed through the instrumentation stockroom in accordance with Material Review disposition.

5.12 VEHICLE CONFIGURATION LIST

The Test Data Group will be responsible for supplying accurate vehicle instrumentation configuration lists to installation and control offices. Configuration lists will be published periodically prior to active testing and on a per test basis during active testing. These lists will show complete information, consisting of measurement number, measurement description, serial number, channel number, etc.



5.13 THE OFF-LIMIT TEST

5.13.1 Application

The off-limit test is considered as part of the design-proof phase, but successful demonstration of a given design margin is not held as a contingency for qualification of any component under test. The tests will determine the design margin relevant to any critical failure mode. The intent is to verify that these are not cumulative tolerance situations which the tests indicate may contribute to unreliability.

5.13.2 Characteristics of the Off-Limit Test

The off-limit test determines design margins and further enables the engineer to predict the potential reliability of a given characteristic or component. There are two distinctly different types of Apollo off-limits tests and they are associated with verifying either stress or performance margins. The first may involve stress to destruction. The tests are accomplished by determining the stress-strength margin related to each characteristic or failure mode and then algebraically summing them up. Some of this work will be done during the development program on the lower levels of assembly, but there is a definite need to verify the results and to examine the effects of interface during qualification.

5.13.3 Off-Limit Tests for Safety Margins

A test should be conducted on ten or more samples for reasonable accuracy. To analyze the failure mode, the characteristics of the environment and of the strength of each component to be utilized must be known. Knowing the stress accurately, one can determine the probability of a failure relevant to that stress as a function of the safety margin and the distribution of strengths associated with the stress. Since establishing an adequate design margin is not the complete answer, the verification of its magnitude and the assurance of a restricted distribution around the mean is also essential. In theory, it is possible to determine the safety or design margins with a very few samples when the distribution of strengths approaches a single value.



6.0 TEST REQUIREMENTS

The development test plan will provide definition of the testing required for all instrumentation equipment. There are three levels of criticality: (1) ground test, (2) unmanned flight, and (3) manned flight. The test requirements will be based on overall mission environment and operational conditions to be encountered by each ground and flight vehicle in these missions. Qualification tests will satisfy all Block I and Block II vehicle mission requirements. Any failure during design proof tests, which include simulation of the most stringent environmental conditions to be experienced during transportation, storage, handling, and the mission, will be cause for positive corrective action and will require complete quality review board (QRB) review. Failures during off-limit tests will be analyzed to determine whether QRB action is required.

Failures experienced during qualification will be analyzed to determine the cause, corrective action, and the degree of requalification necessary. Failures occurring during any phase of qualification will be reported according to the following schedule:

1. Verbal notification within 24 hours
2. Written symptomatic report within 5 days
3. Final analyses and corrective action reports within 15 days.
Failure of a pyrotechnic device will be verbally reported to NASA within 24 hours.

Requalification will be performed when:

1. Design or manufacturing processes are changed to such an extent that the original tests are invalidated.
2. Inspection, test, or other data indicate that a more severe environment or operational condition exists than that for which the equipment was originally qualified.
3. It is jointly agreed upon between NAA/S&ID and NASA/MSD for purposes of sustaining a particular level of effort at a subcontractor's or supplier's facility and/or to provide additional engineering confidence in the capability of the hardware.



The index which follows is an initial list to indicate test requirements on a subsystem basis. This index will be expanded to include all instrumentation equipment and will provide assurance that all equipment will be tested.

A qualification testing summary of instrumentation subsystems is shown in Tables 6-1, 6-2, 6-3, and 6-4.



Table 6-1. Qualification Summary of Instrumentation Subsystems: Operational Measurement

Qualification Test Subsystem Parts			Test Environment																Test Support Status												Remarks	
																			1965													1966
																			1964													1966
Name	Number	Functional	Performance	Hi-temp	Lo-temp	Vacuum	Vibration	Shock	Oxygen	Humidity	Salt	Low-pressure	EMI	Explosion	Acceleration	Acoustic	Temp Cyl	Sand & Dust	Life	Temp/vib	Leakage	Prop Comp	Gas Oxidizer	Self-heat	Thermal Shock	Insul R&S	Destruction	Off-limit				
Pressure measurement	MC 449-0005	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				
Transducer, absolute	ME 449-0005	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				
Transducer, absolute	ME 449-0051	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				
Transducer, absolute	ME 449-0052	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				
Transducer, absolute	ME 449-0055	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				
Signal conditioner	ME 901-0289	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				
Temperature measurement	MC 449-0021	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				
Surface element	ME 449-0029	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				
Surface element	ME 449-0030	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				
Integral tubing	ME 449-0034	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				
Transducer, temperature	ME 449-0050	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				
Signal conditioner	ME 901-0291	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				
Temperature measurement	MC 432-0082																															
Surface element	ME 432-0082	X					X		X	X													X	X	X							
Mass flow measurement	MC 449-0015																															
Transducer, mass flow	ME 449-0015	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				
Data distribution panel Accessible	V16-754000	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				
Inaccessible	V16-754002	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				
Current limiter	V14-750151	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				
	V14-750156	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				
HIGHER LEVEL OF ASSEMBLY TESTS																																
Tests		Objectives and Description																														
BP-14 system compatibility		Preliminary check for integrated systems compatibility.																														
SC 009 system operation verification		Verification of system operation with the mechanical stimulus of installed transducers.																														
Off-limit tests		To be conducted on instrument Criticality 1 components.																														



Table 6-2. Qualification Summary of Instrumentation Subsystems: Heat Shield Measurement

[illegible]



Table 6-3. Qualification Summary of Instrumentation Subsystems: Flight Development Instrumentation Measurement

[illegible]

[illegible]



List of CFE Instrumentation Test Items

Procurement Specification	Subsystem	Remarks
MC 431-0022	TEMPERATURE MEASUREMENT SUBSYSTEM	
ME 265-0007	Thermocouple plug	
ME 361-0004	Thermocouple	
ME 361-0007	Thermocouple	
ME 361-0008	Thermocouple	
ME 161-0015	Reference junction	
ME 901-0338	Power supply - amplifier	
MC 431-0024	ABLATION MEASUREMENT SUBSYSTEM	
ME 431-0024	Ablation sensor	
ME 901-0339	Signal condition	
MC 431-0026	CHAR MEASUREMENT SUBSYSTEM	
ME 431-0026	Char sensor	
ME 901-0332	Signal conditioner	
MC 432-0082	RESISTANCE TEMPERATURE SENSOR	
ME 432-0082	Surface element	To be added per A revision.
ME 432-0096	Probe element (closed)	
ME 432-0097	Probe element (open)	
MC 432-0088	SURFACE HEAT FLUX MEASUREMENT SUBSYSTEM	
ME 432-0088	Sensor — calorimeter	
MC 478-0062	FLOW TRANSDUCER — VENTURI TYPE (To be added per A revision.)	
MC 901-0080	ACOUSTIC MEASUREMENT SUBSYSTEM	
ME 901-0080	Measurement system—acoustic	



List of CFE Instrumentation Test Items (Cont)

Procurement Specification	Subsystem	Remarks
MC 449-0005	STANDARD PRESSURE MEASURING SUBSYSTEM	
ME 449-0054	Differential	
ME 449-0055	Absolute (male fitting)	
ME 901-0288	Signal conditioner (8-pin)	
ME 901-0289	Signal conditioner (6-pin)	
ME 449-0005	Absolute (with tubing)	
ME 449-0051	Absolute (female fitting)	
ME 449-0052	Absolute (flush sensor only)	
ME 449-0053	Absolute (sensor only)	
MC 449-0015	MASS FLOW TRANSDUCER SUBSYSTEM	
ME 449-0015	Transducer — mass flow	
MC 449-0020	LINEAR ACCELERATION TRANSDUCER	
ME 449-0020	Transducer — linear acceleration	
ME 449-0091	Transducer — linear acceleration	
MC 449-0021	STANDARD TEMPERATURE TRANSDUCER	
ME 449-0021	Transducer — temperature	
ME 449-0029	Surface element (only)	
ME 449-0030	Surface element (only)	
ME 449-0032	Transducer — temperature	
ME 449-0040	Transducer — temperature	
ME 449-0034	Integral tubing	
ME 449-0041	Transducer — temperature	
ME 449-0050	Transducer — temperature	
ME 901-0290	Signal conditioner (8-pin)	
ME 901-0291	Signal conditioner (6-pin)	
ME 449-0097	Transducer — temperature	
MC 449-0065	FLOWMETER	
ME 449-0065		To be added per A revision.



List of CFE Instrumentation Test Items (Cont)

Procurement Specification	Subsystem	Remarks
MC 901-0081	CONVERTER, (To be added per A revision.) RESISTANCE TO DC	
MC 901-0112	VIBRATION MEASUREMENT SUBSYSTEMS	
ME 106-0015 ME 411-0255 ME 473-0036	Accelerometer Cable Amplifier	
MC 901-0114	STRESS MEASUREMENT SUBSYSTEM	
ME 432-0089 ME 432-0090 ME 901-0320	Strain gage (leads in tube) Strain gage (leads shielded) Signal conditioner	
MC 901-0479	SIGNAL CONDITIONER (STRAIN GAGE)	
ME 901-0479		To be added per A revision. .
MC 901-0493	DIFFERENTIAL TEMPERATURE	
ME 431-0037 ME 431-0038 ME 473-0060 ME 181-0076	Sensor Sensor Signal conditioner Rack	To be added per A revision.
ME 432-0103	STRAIN GAGE (To be added per A revision.) FLOW METER	
MC 449-0064	THERMAL FLUX	
ME 449-0064	Transducer—thermal flux	
ME 449-0066	TRANSDUCER— (To be added per A revision.) PRESSURE ABSOLUTE (STANDARD RANGE)	
ME 449-0067	TRANSDUCER— (To be added per A revision.) PRESSURE DIFFERENTIAL	



List of CFE Instrumentation Test Items (Cont)

Procurement Specification	Subsystem	Remarks
MC 449-0070	PRESSURE MEASUREMENT SUBSYSTEM	
ME 449-0070	Transducer—pressure	
ME 473-0058	AMPLIFIER— (To be added per A revision.) POWER SUPPLY (2-CHANNEL)	
ME 901-0254	SIGNAL (To be added per A revision.) CONDITIONING ASSEMBLY	
MC 464-0090	POWER SUPPLY REGULATOR DC	
ME 464-0090	Power supply	To be added per A revision.
MC 476-0012	THERMOCOUPLE REFERENCE JUNCTION	
ME 476-0012	Reference junction	To be added per A revision.
MC 470-0100	CONTROL SEQUENCER	
ME 470-0100	Sequencer	To be added per A revision.
MC 431-0040	NUCLEAR PARTICLE DETECTION SUBSYSTEM	
MC 432-0100	WATER pH MONITOR	
ME 432-0100	Water pH monitor	
DATA DISTRIBUTION PANEL		
V16-754000 V16-754002	Accessible Inaccessible	To be added per A revision.
CURRENT LIMITER		
V14-750151 V14-750156		To be added per A revision.



List of GFE Instrumentation Test Items

NASA Part No.	Title
5.24.1.1.1	Gas chromatograph
4.15.	Commutator
4.15.	PAM/FM/FM telemetry
4.15.1.1.1	TM SC electronic package
3.8.2.1.1	9-channel modification package
3.1.1.2.1	90 x 10 HL commutator
4.5.2.1.3	FM transmitter
3.5.1.1.1	5-point calibrator
5.26.1.1.1	SM telemetry modification kit package
3.8.2.2.1	15-channel modification package
3.1.2.4.1	90 x 10 LL commutator
4.5.2.1.4	FM transmitter
4.1.1.1.2	Receiver
4.2.1.1.0	Recorder
4.3.1.1.0	Voltage regulator
ME 435-0026	FQ tape recorder
5.2.1.1.1	Time code generator



Temperature Measurement Subsystem MC 431-0022
 ME 901-0338, ME 161-0015, ME 265-0007, ME 361-0004,
 ME 361-0007, 8

Installation Criticality 1

Qualification Test Criticality 3

Effectivity	Test Conditions
Pre-contract	<p>Development tests: ME 265-0007 (thermo-couple plug) conducted at Plasmadyne Corp. Hyperthermal Facility and Rocketdyne Research Center Rocket Engine Test Facility. NAA standard test points: (10) low (78 Btu/ft²/sec), (8) medium (475 Btu/ft²/sec), (7) high (563 Btu/ft²/sec).</p> <p>Design proof tests: ME 265-0007 (thermo-couple plug) conducted at Plasmadyne Hyperthermal Facility and Rocketdyne Research Center, Rocket Engine Test Facility (final report completed). Test results (temperature vs time) being analyzed on Rocketdyne Research Center computer program. Results to date demonstrate computer program can verify calibration of thermocouples in heat shield material. NAA std test points: (10) low (78 Btu/ft²/sec), (8) medium (475 Btu/ft²/sec), (7) high (563 Btu/ft²/sec).</p> <p>Composite test samples: ME 265-0007 (heat shield and substructure) fabricated using AVCO and NAA/S&ID installation procedures. Will be subjected to verification tests at Autonetics Division, NAA (-65 + 200 F and random vibration 10 to 2000 cps, 0.008 g²/cps to 0.06 g²/cps, 15 min in 3 mutually perpendicular axes).</p> <p>Complete temperature measurement systems: will be tested under combined vibration and temperature with an equivalent system provided by a backup to verify best accuracy and performance (-65 + 200 F and random vibration 10 to 2000 cps, 0.008 g²/cps to 0.06 g²/cps).</p>



Effectivity	Test Conditions
	Combined sensor sample tests: ME 265-0007 thermocouple sensor will be installed with heat flux, pressure, char, etc., to verify compatibility when subjected to hyperthermal environment (reentry) NAA std test point (563 Btu/ft ² /sec).
BP-14, SC 006	Acceptance tests as noted.
SC 008	Qualification test: to C-level. (Refer to Qualification Tests.) Acceptance tests as noted. (Refer to acceptance tests.) Off-limit test required.
SC 009	Qualification test: A-level. (Refer to Qualification Tests.) Acceptance tests as noted. (Refer to Acceptance Tests.)
SC 011, 012, 017	Qualification test: to A-level. (Refer to Qualification Tests.) Acceptance tests as noted. (Refer to Acceptance Tests.) Off-limit test required.
Block-II	Qualification test: to A-level. (Refer to Qualification Tests.)

Qualification Tests

Levels	Test Conditions
C-level	<p>Vibration—Sinusoidal sweep: 6 to 500 cps, 5 min at 2g rms.</p> <p>Continuity—T/C and signal conditioner continuity.</p> <p>Pressure—2000 psig helium, 1 hr ceramic insulation T/C.</p> <p>Lead pull—15±1 lb ceramic insulation T/C, 5±1/2 lb T/C plug assemblies.</p> <p>Input-to-output isolation—100 megohms at 100 VDC signal conditioner.</p> <p>Voltage supply—28 VDC±4, 1.5 transient signal conditioner.</p>



Levels	Test Conditions
	Shield continuity—Discontinuity check ceramic thermocouples. Thermocouple material—0, 25, 50, 75 and 100% range special limit. Temperature/EMF--Calibration 32, 212, 450 F; ceramic thermocouples.
B-level (includes C-level)	Temperature cycling— -65 + 200 F in 30 min, 70 min soak. Vibration test—5 to 2000 cps at 2g, 0.008 g ² /cps at 10 cps to 0.06 g ² /cps at 75 cps, constant amp of 0.06 g ² /cps from 75 to 2000 cps T/C, reference junction, signal conditioner. Combination vibration and temperature—same as above at -65 + 200 F - T/C, reference junction, signal conditioner.
A-level (includes B- and C-levels)	Combine temperature and vibration—60 hr at -65 F, 50 hr at 200 F, and 10 mm Hg T/C reference junction signal conditioner. Acoustics—20 to 9600 cps at 128 to 154 db, 0.0002 dynes/cm ² , T/C reference junction and signal conditioner. EMI—per MC 999-0002.

Off-Limit Tests

A minimum of ten units will be subjected to off-limit tests under simulated reentry environment.

Requirements—Combined vibration, temperature, and overpressure:

Vibration: the same as for the qualification test.

Temperature: to be determined.

Overpressure: five times the rated pressure applied on linear increased input or to 12,000 psia—whichever is less.

Acceptance Tests

Examination of product—Verify materials, design, dimensions, workmanship.

Loop resistance and continuity test—T/C and signal conditioner continuity.

Vibration—Sinusoidal sweep 6 to 500 cps, 5 min, 2g rms.

Insulation resistance—1.0 megohm at 500 VDC between T/C wire and sheath.



Acceptance Tests (Cont)

Temperature vs EMF output—Calibration at 32, 212, and 449 F.
Pressure test—2000 psig helium 1 hr, sheath integrity.
Pull test—13 lb pull on T/C wire while retaining sheath.
Input-to-output isolation test—100 megohms at 100 VDC.
Voltage supply test—28 VDC ± 4 transient 1.5 rated voltage.
Shielding discontinuity test—Discontinuity check on ceramic T/C.
Thermocouple material test—0, 25, 50, 75 at 100% range, special limit check.

Laboratory Systems

The temperature measurement system is calibrated in accordance with MA 0303-0046 which requires an accuracy of 0.1%.

Major Ground Test

SC 008 data evaluation of thermal vacuum test program.

Flight Vehicles

SC 009 flight article and arrangements are presently being completed with NASA/MSD to flight-test thermocouple plus assembly (ME 265-0007) on the scout test vehicle.



Ablation Measurement Subsystem MC 431-0024
ME 431-0024 and ME 901-0339

Installation Criticality 1

Qualification Test Criticality 3

Effectivity	Test Conditions
Pre-contract	Evaluation tests: functional and design verification tests in rocket exhaust and plasma arc (5000 F for 45 sec).
SC 009	Acceptance tests: examination of product to verify materials, dimensions, weight, etc. Range and resolution: seven steps, with each step ± 0.010 inch. Insulation resistance: 100 megohms at 100 VDC, terminals to case. Input impedance: greater than 500 ohms. Output impedance: less than 500 ohms. Output voltage test: 0(+0, -0.1) to 5(+0, -0.1) max signal 6.5 VDC. Vibration: 5 to 27.5 cps ± 1.56 g, 27.5 to 52 cps 0.043 in double amplitude, 52 to 2 kcps ± 6.0 g (10 min). Qualification tests: per C- and B-levels. (Refer to Qualification Tests.) Calibration - 7 points. Off-limit test required
SC 011, 012, and 017	Acceptance tests: same as acceptance tests for SC 009. Qualification tests: per C-, B-, and A-levels. (Refer to Qualification Tests.) Calibration: 7 points. Off-limit test required.
Block II	Same qualification level as for SC 011.



Qualification Tests

Levels	Test Conditions
C-level	<p>Examination of product—To verify materials, weight, dimensions, etc.</p> <p>Resolution—To verify sensor; can measure ablation to within 0.1 inch.</p> <p>Insulation resistance—100 megohms at 100 VDC, terminals to case.</p> <p>Input impedance—500 ohms min.</p> <p>Output impedance—500 ohms max.</p> <p>Voltage test—Output 0 (+0.1, -0.0) to 5 (+0.0, -0.1) VDC and 6.5 VDC.</p>
B-level (includes C-level)	<p>High and low temperature— -65 to +200 F (50 hr each temperature) and 1×10^{-4} mm of Hg.</p> <p>Shock—30 g, 11 msec rise, 1 msec fall.</p> <p>Acceleration—20 g for 5 min.</p> <p>Temperature and vibration—Resonant search 5 to 2000 cps; random vibration at 200 F; 15 min each axis, 10 to 75 cps, 0.01 to 0.06 g^2/cps; 75 to 400 cps, 0.06 to 0.013 g^2/cps.</p>
A-level (includes B- and C-levels)	<p>Thermal shock—Signal condition only, 5 shocks, 65 to +200 F (15 sec each).</p> <p>Acoustic noise—11.2 to 11.2 kcps, 160 db overall, 5 min duration.</p> <p>EMI—Conducted interference, radiated interference, AF conducted, transient conducted, RF radiated, AF induced per MC 999-0002.</p>

Off-Limit Tests

A minimum of ten units will be subjected to off-limit tests under simulated reentry environment.

Requirements—Combined vibration, temperature, and over-pressure:

Vibration: the same as for the qualification test.

Temperature: to be determined.

Overpressure: five times the rated pressure applied as linear increased input or to 12,000 psia—whichever is less.



Laboratory Systems

Calibration: 7 points; 1.6% tolerance.

Major Ground Tests

None.

Flight Vehicles

SC 009: flight data evaluation required before flight of SC 011, 012, and 017.



Char Measurement Subsystem MC 431-0026
ME 431-0026, ME 901-0332

Installation Criticality 1
Qualification Test Criticality 3

Effectivity	Test Conditions
Pre-contract	Performance and design proof tests in rocket exhaust and plasma arc.
SC 009	Qualification tests per C- and B-levels. (Refer to Qualification Tests.) Acceptance tests prior to delivery same as for C-level tests. (Refer to Qualification Tests.) Calibration - 7 points. Off-limit test required.
SC 012	Qualification tests per C-, B-, and A-levels (Refer to Qualification Tests.) Acceptance tests per C-level (Refer to Qualification Tests.) Calibration: 7 points. Off-limit test required.
Block II	Same qualification level as for SC 012.

Qualification Tests

Levels	Test Conditions
C-level	Examination of product—To verify weight, dimensions, materials, etc. Insulation resistance—100 megohms at 50 VDC (pins to case). Input impedance—500 ohms min. Isolation resistance—100 megohms at 50 vdc (input to output). Range and resolution—each step to ± 0.01 inch. Linearity— $\pm 2\%$ from a straight line thru end points.
B-level (includes C-level)	High and low temperature in vacuum— 1×10^{-4} mm of Hg; 50 hr at 200 F; 50 hr at -65 F.



Levels	Test Conditions
	<p>Shock—30 g, 11 msec rise, 1 msec decay.</p> <p>Acceleration test—± 20 g for 5 min.</p> <p>Vibration and high temperature—resonant search 5 to 2000 cps; random vibration at 200 F (5 min), $0.0025 \text{ g}^2/\text{cps}$ to $0.015 \text{ g}^2/\text{cps}$; 10 to 60 cps; constant $0.015 \text{ g}^2/\text{cps}$; 60 to 400 cps, decrease $0.015 \text{ g}^2/\text{cps}$ to $0.003 \text{ g}^2/\text{cps}$, 400 to 2000 cps.</p> <p>Thermal shock—Signal conditioner only, 5 shocks -65 to +200 F within 15 sec.</p>
A-level (includes B- and C-levels)	<p>Acoustic noise—11.2 to 11.2k cps; 157 db overall, 5 minutes.</p> <p>EMI—Susceptibility, conducted susceptibility (power line), transient conduction, radio-frequency radiated, audio frequency induced per MC 999-0002.</p> <p>Leakage—$34 \times 10^{-6} \text{ cc/hr}$ (mass spectrometer method).</p> <p>Calibration: 7 points, max error $\pm 2\%$ F/S all causes.</p>

Off-Limit Tests

A minimum of ten units will be subjected to off-limit tests under simulated reentry environment.

Requirements—Combined vibration, temperature, and overpressure:

Vibration: The same as for the qualification test.

Temperature: To be determined.

Overpressure: Five times the rated pressure applied as linear increased input or to 12,000 psia—whichever is less.

Major Ground Tests

None.

Flight Vehicles

SC 009: will provide operational compatibility flight data will be evaluated to further verify subsequent flight usage.



Surface Heat Flux Measurement Subsystem MC 432-0088
ME 432-0088

Installation Criticality 1

Qualification Test Criticality 3

Effectivity	Test Conditions
Pre-contract	<p>Evaluation tests:</p> <p>A functional test is conducted under simulated reentry heating environments in rocket engine exhaust to confirm and establish basic concept.</p> <p>Material evaluation tests are conducted under simulated reentry environments, providing thermal characteristics of selected refractory materials, arc jet, and rocket engine exhaust at Rocketdyne and Aerospace.</p> <p>A computer program is conducted to determine the behavior of several instrument designs under simulated reentry heating environments as defined by Apollo mission trajectories.</p> <p>A simulated reentry heating composite test is performed to determine the compatibility of the instrument with ablator heat shield material. Rocket engine exhaust and arc jet tests are conducted.</p> <p>Design verification tests:</p> <p>Tests are conducted to determine the capability of the instrument to meet the requirements of the measurement.</p>
SC 009, 011, 012, and 017	Refer to Acceptance Tests and Qualification Tests.
Block II	Qualification tests same as for SC 009 and 011.

Qualification Tests

Combining high temperature and vibration—Stabilized at 800 F, vibrated random 45 min, linear increase from 0.01 g^2/cps at 10 cps to 0.7 g^2/cps at 100 cps; constant at 0.7 g^2/cps from 100 cps to 500 cps; linear decrease to 0.156 g^2/cps at 2000 cps.



Qualification Tests (Cont)

Acoustics—5 min, 11.2 to 11,200 cps, 143 to 118 db (0.0002 dynes/cm²)
Acceleration—20 g max, 3 axes, 5 min in each direction.
Mechanical shock—30 g for 11±1 msec, 3 axes.
Temperature and vacuum—50 hr at -65 F 10⁻⁶ mm Hg; 50 hr at +200 F 10⁻⁶ mm Hg.

Off-Limit Tests

A minimum of ten units will be subjected to off-limit tests under simulated reentry environment.

Requirements—Combined vibration, temperature, and overpressure:

Vibration: the same as for the qualification test.

Temperature: rocket engine exhaust.

Overpressure: Five times the rated pressure applied in linear input or to 12,000 psia—whichever is less.

Acceptance Tests

Examination of product—Verification of material, construction, dimensions workmanship.

Insulation resistance—Between pin and case 100 megohms at 50 VDC ±10%.

Output impedance—No greater than 500 ohms into a 150-kilohm load.

Linearity—Max deviation ±15% full scale.

Repeatability—Max deviation ±10% full scale.

Laboratory Systems

Breadboards, calibrations: A three-point calibration is conducted to determine the EMF vs the temperature curve for the sensor element, to ±15% full-scale.

Major Ground Tests

Composite test models including sensor, heat shield, and substructure will be tested in a hyperthermal testing facility.

Flight Vehicles

SC 009 is first usage and supports subsequent flight vehicles.



Standard Pressure Measuring Subsystem MC 449-0005
 ME 449-0055, ME 449-0054, ME 449-0053, ME 449-0052,
 ME 449-0051, ME 901-0289, ME 901-0288

Criticality 1

Effectivity	Test Conditions
Pre-contract	<p>Evaluation tests:</p> <p>Vibration: 25 g rms to 2 kc random; 0.5 g²/cps combined with 25 g (peak) sinusoidal.</p> <p>Thermal shock: -65 to 200 F change in 70 sec or less.</p> <p>Thermal stability: -65 F for 4 hrs; +200 F for 4 hrs.</p> <p>Vacuum: 1×10^{-6} mm of Hg for 14 days.</p> <p>Acoustics: 162 db overall, to 10 kc for 15 min.</p> <p>Mechanical shock: 30 g for 11 msec \pm 1 msec.</p> <p>Acceleration: 20 g (10 min per axis).</p> <p>Hysteresis, linearity, and repeatability: 11-point calibration, 3 complete loops.</p> <p>Voltage regulation: 90% full-scale pressure applied; input voltage of 28 VDC varied ± 4 v in increments 5 volts; plot input vs output.</p> <p>Output signal to noise ratio: nominal exci- tation voltage applied and white noise of 250 mv (peak-to-peak) at 0 to 10 kc inserted into excitation voltage.</p> <p>Output loading effect and output impedance: apply full-scale pressure; 1 megohm in 10 equal steps; open circuit voltage taken to compute output impedance.</p> <p>Stability: 25%, 100% full-scale pressures and ambient pressures applied for as long as 24 hr.</p> <p>Input/output isolation: high and low of input shorted together; high and low of output shorted together; resistance of these two connections to be checked.</p>



Effectivity	Test Condition
	Insulation test: insulation resistance checked between all connector pins and specimen case; 50 VDC to be applied for this test.
SC 001, 006, and 008 BP-14	Acceptance tests on qualification parts: performed before and after each level of qualification testing. Qualification testing: C-level (Refer to Qualification Tests.) Acceptance test on production parts: (Refer to Acceptance Tests.) Off-limit test required.
SC 009	Acceptance test on qualification parts: performed before and after each level of qualification testing. Qualification testing B-level: refer to Qualification Tests. Acceptance test on production parts: refer to Qualification Tests. Off-limit test required.
SC 011, 012 and 017	Acceptance test on qualification parts: performed before and after each level of qualification testing. Qualification testing A-level: refer to Qualification Tests. Acceptance test on production parts: refer to Acceptance Tests. Off-limit test required.
Block II	Qualification tests to A-level same as for SC 012

Qualification Tests

Levels	Test Conditions
C-level	<p>Vibration</p> <p>Sinusoidal—resonant search; 3 axes, 10 minutes per axes. Constant sweep of 2 g from 5 cps to 2 kcps.</p> <p>Random—25 g rms 0.3 g²/cps max. 3 axes, 15 minutes per axes. Spectrum density; linear increase from 0.02 g²/cps at 5 cps to 0.3 g²/cps at 100 cps, 0.3 g²/cps at 100 cps constant to 2000 cps.</p> <p>Acoustic—37.5 to 9.6 kc at 116 to 158 (+3, -0) db.</p>



Levels	Test Conditions
	High temperature—Ambient to 200 F in 20 min; 200 F for 90 min. Low temperature—Ambient to -65 F in 20 min; -65 F for 90 min.
B-level (includes C-level)	Acceleration—20 g, 300 sec, each direction 3 axes. Mechanical shock—30 g in 3 axes, each direction 11 msec rise time; 1 msec delay time. Combined temperature and vibration—200 F for 15 min; -65 F for 15 min each axis. Propellant compatibility—50/50 UDMH and hydrazine +80 F for 24 hr; N ₂ O ₄ at +55 F for 24 hr. Gaseous oxidizer—+70 F relative humidity 80%, small amt of N ₂ O ₄ .
A-level (includes B- and C-levels)	Vacuum— 1×10^{-6} mm Hg, 336 hr, 100 hr specimen operating. Combined high and low temperature in vacuum— 1×10^{-6} mm Hg, 100 hr: 50 hr at -65 F, 50 hr at +200 F. Leakage— 34×10^{-6} cm ³ /ft ³ /hr max. EMI—MC 999-0002. Salt fog—per Mil-Std-810 for 48 hr. Oxygen—humidity: per Mil-Std-810 for 240 hr.

Off-Limit Tests

A minimum of three units will be subjected to off-limit tests under simulated flight environment.

Requirements—Combined vibration, temperature, and overpressure:

Vibration: the same as for the qualification test.

Temperature: -65 F and at +200 F.

Overpressure: five times the rated pressure applied as linear increased input or to 12,000 psia—whichever is less.

Acceptance Tests

Examination of product—Verify materials, design, construction, dimensions, and markings.

Insulation resistance—100 VDC between each connector pin and case for 2 min; resistance to be greater than 100 megohms.

Input-to-output isolation—Input leads shorted together and output leads shorted together; with 100 VDC across these 2 connectors, resistance to be greater than 100 megohms.



Acceptance Tests (Cont)

Noise feedback test—With 28 VDC provided to specimen, record peak-to-peak voltage level indicated on oscilloscope. The signal is passed through 20-kc low-pass filter before being displayed on scope. Noise voltage level not to exceed 10 mv peak-to-peak to 20 kc.

Output regulation test—Specimen pressurized to 50% full-scale; with input voltage varied from 24 to 32 VDC, output readings not to vary more than ± 10 m VDC.

Input current test—With 28 VDC applied to specimen, input current to be recorded and not to exceed 56 ma.

Output noise test—28 VDC to specimen, output indicated on oscilloscope not to exceed 10 mv peak-to-peak to 10 kc.

Calibration—7 points, increasing and decreasing, 2 loops; establishes repeatability; end points established; hysteresis and linearity established.

Temperature test—28 VDC supplied to specimen exposed to -65 F and +200 F and stabilized for 45 min in each environment. Zero and full scale pressures to be applied in each temperature range. Temperature effects such as zero and sensitivity shift to be computed by comparison with ambient temperature.

Vibration—Sinusoidal vibration test: 7 cps to 27.5 cps constant peak-to-peak acceleration level of 1.56 g; from 27.5 cps to 52.0 cps constant peak-to-peak displacement level of 0.043-inch double amplitude from 52.0 cps to 2000 cps constant peak-to-peak acceleration level of 6 g; from 2000 cps to 52.0 cps constant peak-to-peak acceleration level of 6 g; from 52.0 cps to 27.5 cps constant peak-to-peak displacement level of 0.043-inch double amplitude. 27.5 to 7 cps constant peak-to-peak acceleration level of 1.56 g. Time duration 10 minutes.

Laboratory Systems

Calibration: per NAA MA0204-0104.

Major Ground Tests

BP-14, TF2, SC 001, SC 006, SC 008: provide operational compatibility data for further verification for flight use.

Flight Vehicles

SC 009 is first flight usage.



Mass Flow Transducer Subsystem MC 449-0015
ME 449-0015

Criticality 1

Effectivity	Test Conditions
Pre-contract	Analytical investigation of different types of flow measurement instruments performed. Thermal type mass flow transducer chosen as method to satisfy particular flow measurement in question. No evaluation testing of hardware performed.
SC 001	Prequalified parts installed on SC. Acceptance tests performed on parts. End point tolerances of output voltage test and temperature sensitivity requirements waived.
BP-14	Prequalified parts used. Acceptance tests performed on units. (BP-14 fuel cells are undergoing tests in EDL.)
SC 006 and 008	Units passing C-level test to be used. (Refer to Qualification Tests.) Units to pass acceptance tests. (Refer to Acceptance Test.) Off-limit tests required.
SC 011, 012 and subsequent	Units passing A-level qualification tests to be used. (Refer to Qualification Tests.) Units to pass acceptance tests: same as for SC 006 and 008. Off-limit tests required.
Block II	A-level-qualified parts to be used. (Same as for SC 012.)



Qualification Tests (MC 449-0015)

Levels	Test Conditions
C-level	<p>Vibration—Resonant search 5 to 2000 cps at 0.5 inches double amplitude or 3 g max.</p> <p>Random—Linear increase from 0.0083 g²/cps at 20 cps to 0.04 g²/cps at 100 cps. Constant at 0.04 g²/cps from 100 cps to 2000 cps.</p> <p>Acoustics—11.2 cps to 11,200 cps at 134 db, 5 min.</p> <p>EMI—Test to MC 999-0002</p> <p>High-low temperature in vacuum—Ambient to -65 F at 1 x 10⁻⁶ mm Hg in 2 hr; -65 F at 1 x 10⁻⁶ mm Hg for 50 hrs; -65 F at 10⁻⁶ mm Hg to +200 F at 10⁻⁴ mm Hg in 2 hr; +200 F at 10⁻⁴ mm Hg for 50 hrs.</p>
B-level (includes C-level)	<p>Mechanical shock—30 g; 11±1 msec, 1 msec decay, each direction 3 axes.</p> <p>Acceleration—20 g for 5 min in each direction at 3 axes.</p> <p>High temperature and vibration—Vibration test (random) described in C-level except transducer at 200 F.</p>
A-level (includes B- and C-levels)	<p>High and low temperature: of medium calibration of transducer with medium at -125 F and +100 F for Class A transducers and -175 F and +100 F for Class B transducers.</p> <p>Thermal shock—Temperature change from -65 F to +200 F in 2.5 min.</p>

Off-Limit Tests

A minimum of three units will be subjected to off-limit tests under simulated flight environment.

Requirements—Combined vibration, temperature, and overpressure:

Vibration: The same as for the qualification test.

Temperature: -65 and at +200 F.

Overpressure: Five times the rated pressure applied as linear increased input or to 12,000 psia—whichever is less.



Acceptance Tests

Examination of product—Check physical configuration for compliance with SCD.

Insulation resistance—Check to insure that resistance between terminals A, B, C, D, and F exceeds 100 megohms at 50 VDC.

Isolation resistance—Test to insure that isolation resistance between power and signal leads exceeds 100 megohms at 50 VDC.

Input current—Check to insure that current drain does not exceed 100 ma.

Noise feedback—Test to insure that noise feedback to power source does not exceed 10 mv peak-to-peak to 20 kc.

Output voltage—Check end points 0.0 (+0.1, -0.0) to 5.0 (+0.0, -0.1) and verify that output noise does not exceed 10 mv peak-to-peak to 10 kc.

Voltage regulation—Test to insure that output changes by less than 10 mv when input power varies from 24 to 32 VDC.

Repeatability and hysteresis—Test to insure that hysteresis and repeatability errors do not exceed 1% of full scale.

Proof pressure—Test to insure that calibration does not shift after application of 2 x operating pressure.

Acceptance vibration—Apply 0.5 inch double amplitude or 6 g max vibration from 5 to 2000 cps in 3 axes.

High and low temperature—Check for thermal drift by exposing transducer to temperatures from ambient to +200 F, to -65 F, and back to ambient in 6 hr. Drift less than 0.02% of full scale per degree F.

Laboratory System

Calibration: the transducer is to be given an 11 point calibration at NAA. Calibration points are to be at 10% increments of full scale. No point on the calibration curve may vary from the standard calibration curve by more than 1.5% of full-scale output.

Ground Tests

Transducers installed in laboratory fuel cell test setup for functional tests in simulated spacecraft operation conditions.

BP-14: transducers installed for functional tests and for systems compatibility tests.

SC 001: transducers installed for dynamic tests.

SC 006 and 008: transducers installed for functional tests during simulated space environments.

Flight Vehicles

SC 011 is first usage.



Linear Acceleration Transducer MC 449-0020
ME 449-0020

Criticality 3

Effectivity	Test Conditions
Pre-contract	<p>Evaluation tests:</p> <p>Vibration: random $0.5 \text{ g}^2/\text{cps}$ combined with 25 g (peak) sinusoidal for 15 min/axis.</p> <p>Thermal shock: change in 70 sec from -65 F to 200 F.</p> <p>Thermal stability: -65 F for 4 hr and +200 F for 4 hr.</p> <p>Shock: 30 g (peak) $11 \pm 1 \text{ ms}$, 1/2 sine wave in each axis.</p> <p>Acceleration: 20 g static for 10 min per axis.</p> <p>Acoustic: 152 db overall from 5 to 9600 cps for 15 min.</p> <p>Altitude: 10^{-6} mm of Hg for 14 days.</p> <p>Voltage regulation: $28 \pm 4 \text{ VDC}$.</p> <p>Stability: output vs time for 24 hr.</p> <p>Insulation and isolation resistance test: 100 megohms at 100 VDC.</p> <p>Power consumption: from 24 to 32 VDC into a load of 25 k to 1 megohm.</p> <p>Gain stability: from 24 to 32 VDC.</p> <p>Hysteresis, linearity and repeatability: transducer calibration check.</p>
BP-14 and SC 006	<p>Acceptance testing for C-level qualification test items.</p> <p>Examination of product: check for compliance with SCD.</p> <p>Insulation resistance test: check for insulation resistance b/T terminals and case ground; 100 megohms at 100 VDC.</p> <p>Isolation resistance test: check for isolation resistance b/T power and signal terminals 100 megohms at 100 VDC.</p> <p>Input current test: check for power consumption (less than 64 ma at 32 v).</p>



Effectivity	Test Conditions
BP-14 and SC 006 (Cont)	<p>Output noise test: check for signal output noise (less than 20 mv peak-to-peak.</p> <p>Nonlinearity, hysteresis, and repeatability: transducer calibration.</p> <p>Frequency response: check for transducer frequency response.</p> <p>Qualification testing C-level</p> <p>Vibration: random $0.3g^2/cps$, 15 min per axis.</p> <p>Acoustics: 159 db overall from 11.2 to 11,200 cps for 5 min.</p> <p>High and low temperature: -65 F for 4 hr and +200 F for 4 hr.</p> <p>EMI: electromagnetic interface test per MC 999-0002.</p> <p>Acceptance testing for production items: same acceptance testings as used for qualification test items, plus the following:</p> <p>Temperature test: -65 F for 1 hr and +200 F for 1 hr.</p> <p>Vibration test: 0.036 in double amplitude from 5 to 52 cps and 5 g (peak) from 52 to 2 k cps.</p> <p>In-house calibration</p> <p>Transducers to be calibrated per NAA specification MA0304-0023.</p> <p>Linearity, hysteresis, repeatability, and frequency response.</p>
SC 009	<p>Qualification testing B-level</p> <p>Shock: 0 g (peak) 11 ± 1 ms, 1/2 sine for each axis.</p> <p>Acceleration: 30 g static for 5 min in each direction of 3 axes.</p> <p>High and low temperature during vibration: random $0.3 g^2/cps$, from 5 cps to 2000 cps for 15 min per axis, at -65 F and at +200 F.</p> <p>Acceptance testing for production items: same test as used for C-level</p> <p>In-House Calibration: same calibration as in C-level.</p>
SC 012	<p>Qualification testing A-level</p> <p>Vacuum testing: 10^{-6} mm of Hg for 100 hr.</p> <p>High and low temperature in vacuum: 10^{-6} mm of Hg for 50 hr each at -65 F and +200 F.</p>



Effectivity	Test Conditions
SC 012 (Cont)	Salt fog test: test per Mil-Std-810 for 48 hr. Oxygen-humidity test: test per Mil-Std-810 for 240 hr. Acceptance testing for production items: same test as used for C-level. In-house Calibration: same calibration as in C-level.
Block II	Qualification level will be A-level—same as for SC 012.



Standard Temperature Transducer Subsystem MC 449-0021

ME 901-0291, ME 449-0034,

ME 449-0030, ME 449-0029,

ME 449-0050, ME 901-0290

ME 901-0047

Criticality 1

Effectivity	Test Conditions
Pre-contract	<p>Evaluation tests:</p> <p>Vibration: 25 g rms to 2 kc random; 0.5 g²/cps combined with 25 g (peak) sinusoidal; 30 min each axis.</p> <p>Thermal shock: -65 to +200 F change in 70 sec or less.</p> <p>Thermal stability: -65 F for 4 hrs; +200 F for 4 hr.</p> <p>Vacuum: 1 x 10⁻⁶ mm Hg for 14 days.</p> <p>Acoustics: 162 db overall to 10 kc 15 min.</p> <p>Mechanical shock: 30 g, 11 ms ±1 ms, each axis.</p> <p>Acceleration: 20 g, 10 min, each axis.</p> <p>Hysteresis:</p> <p>Linearity:</p> <p>Repeatability: 6-pt calibration, 3 runs.</p> <p>Voltage regulation: ±10 mVDC max, 28±4 VDC.</p> <p>Output noise: ±10 mVDC to 10 kc.</p> <p>Signal load and output Z: signal load from 50 k to 1 megohm.</p> <p>Input/output isolation: 100 megohms at 100 VDC.</p> <p>Insulation resistance: pin to case 100 megohms at 100 VDC.</p>
SC 001	<p>Acceptance tests on qualification parts: performed before and after each phase of qualification testing. (Refer to Acceptance Tests.)</p> <p>Qualification tests: C-level. (Refer to Qualification Tests.)</p> <p>NAA calibration: MA0204-0116.</p>



Effectivity	Test Conditions
SC 009	Acceptance tests on qualification parts. Qualification tests: B-level. NAA calibration: MA0204-0116. Off-limit tests required as noted.
SC 012 and Subsequent	Acceptance tests on qualification parts. Qualification tests: A-level NAA calibration: MA0204-0116. Off-limit tests required as noted.
Block II	Same as for SC 012 A-level equipment.

Qualification Tests

Levels	Test Conditions
C-level	Vibration—Resonant search: 5 to 2 cps, 2 g, three axes. Random—24 g rms ($0.3 \text{ g}^2/\text{cps}$ max). Acoustic—37.5 to 9.6 kc; 160 db overall High temperatures—Ambient to +200 F in 20 min; +200 F for 90 min. Low temperature—Ambient to -65 F in 20 min; -65 F for 90 min.
B-level (includes C-level)	Acceleration—20 g, 300 seconds, each direction in 3 axes. Mechanical shock—30 g 11 msec rise time, 1 msec decay time, each direction in 3 axes. Combined temperature and vibration—Paragraph 4.4.6 and +200 F, 15 min; -65 F, 15 min. Propellant compatibility—50/50 UDMH and hydrazine 80 F for 24 hr, N_2O_4 55 F for 24 hr. Gaseous oxidizer—70 F, rel humidity 80% gaseous N_2O_4 .
A-level (includes B- and C-level)	Vacuum— 1×10^{-6} mm Hg, 336 hr, 100 hr specimen operation. Combined high and low temperature in vacuum— 1×10^{-6} mm Hg -100 hr total: 50 hr at -65 F, 50 hr at +200 F. Leakage— $34 \times 10^{-6} \text{ cm}^3/\text{hr}$ max. EMI—Per MC 999-0002. Salt fog: per Mil-Std -810 for 48 hr. Oxygen-humidity; per Mil-Std -810 for 240 hr.



Off-Limit Tests*

A minimum of three units will be subjected to off-limit tests under simulated flight environment.

Requirements—Combined vibration, temperature, and overpressure:

Vibration: The same as for the qualification test.

Temperature: -65 F and at +200 F.

Overpressure: 5 times the rated pressure applied as linear increased input or to 12,000 psia—whichever is less.

*Effective on ME 449-0050 and ME 901-0097, only.

Acceptance Tests

Examination of product—Verification of materials, design, construction, dimensions, and markings.

Insulation resistance—Pin to case: 100 megohms or greater at 100 VDC.

Input-to-output insulation—Input-to-output: resistance 100 megohm or greater at 100 VDC.

Noise feedback—10 mv peak-to-peak max, to 20 kc.

Output regulation—24 to 32 VDC input regulated to ± 10 mVDC output.

Input current—56 ma max.

Output noise—10 mv peak-to-peak max, to 10 kc.

Calibration—6 points, 0 to 100% full-scale, two runs.

Temperature environment—45 min at +200 F, 45 min at -65 F.

Vibration—6 g sine for 5 min each axis.

Laboratory Systems

Calibration: $\pm 3\%$ of best fit straight line repeatable $\pm 0.2\%$ full-scale.

Major Ground Tests

SC 001: Usage will provide compatibility and operational performance data.

Flight Vehicles

SC 009: Evaluation of equipment operation and data will be used to verify further usage for subsequent flight vehicles.



Acoustic Measurement Subsystems MC 901-0080
ME 901-0080

Criticality 3

Effectivity	Test Conditions
	<p>Developmental: high and low temperature were conducted by the supplier to establish basic parameters such as microphone diaphragm tension and diaphragm to backplate spacing.</p>
Pre-contract	<p>Evaluation tests:</p> <p>Examination of product: inspect for materials, design, construction, weight, dimensions, etc.</p> <p>Insulation resistance: measure 100 megohms or more between each terminal and case.</p> <p>Isolation resistance: measure 100 megohms or more between power-in and signal-out.</p> <p>Power consumption: input power of operating system is to be less than 2.5-w.</p> <p>Output voltage: measure output voltage with full-scale sound input to be 5 v peak-to-peak ± 0.3 db.</p> <p>Linearity: record input sound from scale max to scale min and corresponding output voltage—max deviation from best straight line not to exceed 0.5 db.</p> <p>Frequency response: record output voltage vs frequency at 100 db.</p> <p>SPL: response curve to be a flat ± 1 db from 10 cps to 10 kcps.</p>
SC 009	<p>Qualification testing: B-level. (Refer to Qualification Tests.)</p> <p>Acceptance test: all pre-qualification acceptance test plus the following:</p> <p>Temperature: Conduct above frequency response test at 140 F and again at 40 F.</p>



Effectivity	Test Conditions
	<p>Vibration: measure $+2.5 \pm 0.05$ VDC bias voltage output with no input while running the following vibration profile: 0.036 in double amplitude, 5 to 52 cps and 5 g peak 52 to 2000 cps, 10 min sweep in most sensitive axis.</p> <p>Calibration: calibration test to be linearity test as already stated.</p>
SC 011	All tests for SC 009 are applicable, plus A-level qualification test.
SC 012 and subsequent	Qualification tests: A-level.

Qualification Tests

Levels	Test Conditions
C-level	<p>Vibration—Resonant, 5 to 2000 cps up to 2g 3 axes; random, 10 to 60 cps linear increase 0.0025 to $0.015 \text{ g}^2/\text{cps}$, 60 to 2000 cps constant at $0.015 \text{ g}^2/\text{cps}$.</p> <p>Acoustic—11.2 cps to 11.2 k cps at 137 db SPL overall, 7 min.</p> <p>High temperature—140 F for 4 hr.</p> <p>Low temperature—40 F for 4 hr.</p> <p>EMI—MC 999-0002B conducted interferences—30 cps to 25 megacycles; radiated interference 0.015 to 10 kmc; transients 50 v, 10 msec, 10 PPS; susceptibility—30 cps to 10 kmc.</p>
B-level (includes C-level)	<p>Acceleration—20 g for 5 min, in each direction of 3 axes.</p> <p>Mechanical shock—30 g, 11 ± 1 msec, in each direction of 3 axes.</p> <p>High-low temperature and vibration—High and low temperature simultaneous, vibration for C-level, except for exposure time (15 min).</p> <p>Voltage supply—Measurement system is to operate within requirements specified herein when supplied with input voltage of 28 ± 4 VDC, having maximum noise of 2 v peak-to-peak up to 10,000 cps</p>



Levels	Test Conditions
B-level (Cont)	<p>Transients up to 1.5 times rated voltage of 200 msec duration must not damage the system or cause out-of-tolerance performance.</p> <p>Power consumption—Power consumed by the system not to exceed 2.5 w.</p> <p>Output voltage—Output voltage of the measurement system is to be directly proportional to the input sound pressure level 1.77 volts rms ± 0.3 db (5 v peak-to-peak) at full scale on plus 2.5 ± 0.05 VDC bias.</p> <p>Output over voltage to be limited to 7 v peak-to-peak max.</p> <p>Frequency response—Overall frequency response of the measurement system to be flat within ± 1 db over the frequency range of 10 to 10,000 cps, at pressures ranging from 5 to 15 psia, using 100 cps as the reference frequency.</p> <p>Linearity—Max deviation from the best straight line through the calibration point not to exceed ± 0.5 db of the reading.</p> <p>Repeatability—Measurement system to be better than $\pm 1\%$ of full scale.</p> <p>Output noise level—Output noise level of the measurement system is not to exceed 10 mv rms to 10,000 cps.</p> <p>Load impedance—The measurement system is to operate within specifications into a load of 25,000 ohms to 1.0 megohm.</p> <p>Isolation resistance—The isolation resistance between (connected together) power input terminal and (connected together) signal output terminals to be greater than 100 megohms at 50 VDC.</p> <p>Insulation resistance—The insulation resistance between any terminal and case, except where the terminal is designated "case ground," is to exceed 100 megohms at 50 VDC.</p> <p>Noise feedback—Noise feedback from the measurement system to the 28-volt power buss is not to exceed 10 mv peak-to-peak to 20,000 cps.</p>



Levels	Test Conditions
B-level (Cont)	<p>Operating life—The measurement system is to have a minimum operating life of 400 hr without maintenance.</p> <p>Service life—The measurement system is to have a minimum service life of 1400 hr with periodic maintenance. Parts requiring maintenance during the service period will be specified by the manufacturer and will be subject to approval of NAA/S&ID.</p> <p>Voltage regulation—The output signal is to change less than ± 10 m VDC over the 28 ± 4 VDC input excitation range.</p> <p>Gain and bias temperature stability—The rms output voltage of the system must not deviate more than $\pm 2.0\%$ of full-scale, and the dc bias voltage must not deviate more than $\pm 2.0\%$ of the pre-set bias voltage over the temperature range from 40 to 140 F.</p> <p>Vibration sensitivity—The system vibration sensitivity must be less than 80 db SPL</p>
A-level (include B-level and C-level)	<p>Oxidation—The unit is to be operated for 360 hr in a 100% O₂ environment.</p>



Vibration Measurement Subsystems MC 901-0112
ME 473-0036, ME 106-0015, ME 411-0255

Criticality 3

Effectivity	Test Conditions
Pre-contract	<p>Evaluation test program at the Boeing Co., Seattle, Washington and NAA/S&ID.</p> <p>Vibration: random $0.5 \text{ g}^2/\text{cps}$ combined with 25 g (peak) sinusoidal for 15 min/axis.</p> <p>Thermal shock: change in 70 sec from -65 F to +200 F.</p> <p>Thermal stability: -65 F for 4 hr and +200 F for 4 hr.</p> <p>Shock: 30 g (peak) 11 ± 1 msec $1/2$ sine wave, per axis.</p> <p>Acceleration: 20 g static for 10 min per axis.</p> <p>Acoustic: 152 db overall from 5 to 9600 cps for 15 min.</p> <p>Altitude: 10^{-6} mm of Hg for 14 days.</p> <p>Voltage regulation: 28 ± 4 VDC.</p> <p>Stability: output vs time for 24 hr.</p> <p>Insulation and isolation resistance test: 100 megohms minimum at 100 VDC.</p> <p>Power consumption: from 24 to 32 VDC into a load of 25 k to 1 megohm.</p> <p>Gain stability: from 24 to 32 VDC.</p> <p>Accelerometer cross-axis sensitivity: measured while rotating around sensitive axis.</p>
SC 001	<p>Acceptance testing for qualification test items.</p> <p>Examination of product: check for compliance with SCD.</p> <p>Frequency response: system response from 20 to 5000 cps for Type I amplifier, 5 to 250 cps for Type II amplifier, and 5 to 600 cps for Type III amplifiers.</p> <p>Input current: check for system power consumption.</p>



Effectivity	Test Conditions
SC 001 (Cont)	<p>Output voltage test: system check for full scale output.</p> <p>Output noise test: check for system output noise.</p> <p>Linearity test: system check for linearity from 0 to 100% full-scale output.</p> <p>Isolation resistance test: check for isolation resistance b/T power input terminals and signal output terminals (100 megohms at 100 VDC).</p> <p>Insulation resistance test: check for insulation resistance b/T all terminals and case ground (100 megohms at 100 VDC).</p> <p>Qualification tests C-level</p> <p>Vibration: random $0.9 \text{ g}^2/\text{cps}$, 15 min per axis.</p> <p>Acoustics: 169 db overall from 11.2 to 11,200 cps; test time 5 min.</p> <p>High and low temperature: -65 to +200 F for amplifier; -65 to +400 F for accelerometer while operating as a system. Test time 4 hr.</p> <p>EMI: Electromagnetic interference test per MC 999-0002.</p> <p>Acceptance testing for production items: same acceptance testing as used for qualification test items, plus the following:</p> <p>Response to temperature test: -65 for 1 hr and +200 F for 1 hr.</p> <p>Vibration test: 0.036 in double amplitude from 5 to 52 cps and 5 g (peak) from 52 to 2000 cps.</p> <p>In-house calibration: systems to be calibrated per NAA specification MA 0304-0022 linearity and frequency response.</p>
SC 009	<p>Qualification testing phase B-Level</p> <p>Accelerometer response to pressure pulse—140 psi, 20 ms adiabatic pulse. High and low temperature during vibration—random $0.9 \text{ g}^2/\text{cps}$, from -65 F to +200 F for 15 min per axis.</p>



Effectivity	Test Conditions
SC 009 (Cont)	<p>Gaseous oxidizer: system subjected to N_2O_4 at 70 F for 60 min.</p> <p>Acceptance testing for production items: same test as used for C-level.</p> <p>In-house calibration: systems to be calibrated per NAA specification MA 0304-0022 linearity and frequency response.</p>
SC 012	<p>Qualification testing A-level</p> <p>Vacuum testing: 10^{-6} mm of Hg for 100 hr.</p> <p>High and low temperature in vacuum test: 10^{-6} mm of Hg for 50 hr each at -65 F and +200 F.</p> <p>Salt fog test: system test per Mil-Std-810 for 48 hr.</p> <p>Oxygen-humidity test: system test per Mil-Std-810 for 240 hr.</p> <p>Oxidation explosion: system test per Mil-E-5272 for 360 hr.</p> <p>Acceptance testing for production items: same test as used for C-level.</p> <p>In-house calibration: systems to be calibrated per NAA specification MA 0304-0022.</p>
Block II	<p>Qualification level will be A, same as for SC 012.</p> <p>Acceptance tests same as for SC 012.</p>



Stress Measurement Subsystems MC 901-0114
ME 432-0090, ME 432-0089, ME 901-0320

Criticality 3

Effectivity	Test Conditions
Pre-contract	<p>Evaluation for selection (strain gage only)</p> <p>Gage resistance at room temperature; strain limit at room temperature; -260 F and +600 F; thermal output at -260 F and +600 F.</p> <p>Drift and leakage resistance at -260 F, room temperature and +600 F; gage factor change with temperature -260 F and +600 F.</p> <p>Application tests: welding and bonding studies—welding to cress steel and aluminum, bonding to aluminum for 200 F application.</p>
BP-14	<p>Acceptance tests: examination of product, verification of materials, design, weight, etc.</p> <p>Insulation resistance: 100 megohms from terminals to case (50 VDC).</p> <p>Input to output isolation: 100 megohms at 50 VDC.</p> <p>Noise feedback: 10 mv peak-to-peak to 20 kc from system to power source.</p> <p>Output regulation: ± 4 VDC on input, ± 5 mv on output.</p> <p>Input current: 63 ma max.</p> <p>Output voltage: 0(+0.05, -0.0) to 5(+0.0, -0.05) VDC.</p> <p>Output noise—30 mv peak-to-peak.</p> <p>Vibration—5 to 52 cps at 0.36 in double amplitude and 52 to 2 kc at ± 5 g.</p> <p>High and low temperature: 200 F for 60 minutes and -65 F for 60 min.</p> <p>Calibration: signal conditioner only 5 points open loop $\pm 0.1\%$.</p> <p>Qualification tests: tests per C-level. (Refer to Qualification Tests.)</p> <p>In-house calibration: signal conditioner only 5 points open loop $\pm 0.1\%$.</p>



Effectivity	Test Conditions
SC 008	Acceptance tests: same as for BP-14 acceptance tests. Qualification tests: D-level tests. (Refer to Qualification Tests.) In-house calibration: signal conditioner only.
SC 009	Acceptance tests: same as for BP-14 acceptance tests. Qualification tests: Tests per B-level. (Refer to Qualification Tests.) In-house calibration: signal conditioner only.
SC 012	Acceptance tests: same as for BP-14 acceptance tests. Qualification tests: A-level tests. (Refer to Qualification Tests.) In-house calibration: signal conditioner only.
Block II	Qualification tests same as for SC 012. Acceptance tests same as for SC 012.

Qualification Tests

C-level	<p>Combined temperature and vibration (random) — sensor: 10 to 100 linear increase from 0.007 to 0.7 g^2/cps; 100 to 500 cps constant at 0.7 g^2/cps; 500 to 2000 cps linear decrease from 0.7 to 0.156.</p> <p>Signal conditioner — 10 to 75 cps linear increase from 0.01 to 0.06; 75 to 425 cps constant at 0.06; 425 to 2000 cps linear decrease from 0.06 to 0.13.</p> <p>10 min each axis at -65 F, room temperature, and +200 F; 10 min each axis at 600 F (strain sensor only).</p> <p>Humidity — 10 cycles from +68 to 160 F at 95% relative humidity 240 hr.</p> <p>EMI — Per MC 999-0002</p>
B-level (includes C)	<p>Mechanical shock — 30 g for 3 axes, 11 msec for rise; 1 msec for decay.</p> <p>Gaseous oxidizer — N_2O_4 for 1 hr at 70 F, air dry 24 hr.</p>
A-level (includes B-, and C-)	Oxidation test — 100% oxygen at 5 psia for 100 hr.



Thermal Heat Flux Subsystem MC 449-0064
ME 449-0064

Criticality 1

Effectivity	Test Conditions
Pre-contract SC 009, 011, 017, 020	<p>Development tests: functional tests will be conducted under simulated reentry heating environments (50 Btu ft²/sec - 90 sec in rocket exhaust), to confirm and establish basic concept.</p> <p>Simulated reentry heating composite test performed to determine compatibility of instrument with abalator heat shield material in rocket engine exhaust.</p> <p>Design verification: tests will be conducted to determine the capability of the instrument to meet the requirements of the measurement.</p> <p>Acceptance test: examination of product — inspection will be conducted to verify that the material, design construction, dimensions, markings, weight, and workmanship comply with requirements.</p> <p>Pull test (cable junction): a direct pull force of 12 pounds per square inch will be gradually applied to the cable at ambient temperature. The test duration will be 1 minute. The pull force is gradually removed.</p> <p>Performance tests: a complete calibration test will be conducted on each transducer. The test points of the calibration curves are to be within specified tolerances, $\pm 5\%$ of full scale. The calibration test will establish the performance characteristics of the transducer.</p>

Qualification Tests

Combined vibration and temperature — The temperature is stabilized at 200 F, random vibration for 45 minutes (15 minutes in each of the three mutually perpendicular axes). Linear increase from 0.01 to 0.7 g²/cps at 10 to 100 cps, constant at 0.7 g²/cps at 100 to 500 cps, and linear decrease from



Qualification Tests (Cont)

0.7 to 0.156 g^2 /cps at 500 to 2000 cps. Output signal during vibration will not deviate more than $\pm 2.0\%$ of full scale from the static output.

Acoustics—11.2 to 11.2 kc at 157 SPL for 120 sec. The output is monitored during the test.

Acceleration test—20 g for 300 sec along each axis of the three mutually perpendicular axes. The output of the specimen is monitored during the test.

Thermal shock test—from ambient to -65 F; stabilization. The temperature is raised to +250 F within 180 sec. The output signal is monitored during and after the test. The calibrated output signal change must not be more than 3% of full scale.

Cable-pull and high temperature test—The temperature is stabilized at 400 F. A direct pull force of 12 pounds per square inch is applied for 1 minute and then gradually removed. Inspection for chipping at junction of cable and transducer is made.

Acceptance test, examination of product-inspection is made to verify that the material, design construction, dimensions, markings, weight, and workmanship comply with requirements.

Pull test (cable junction)—a direct pull force of 12 pounds per square inch will be applied gradually to the cable at ambient temperature. The test duration will be 1 minute; then the pull force will be gradually removed.

Performance tests—a complete calibration test will be conducted on each transducer. The test points of the calibration curves will be within specified tolerances $\pm 5\%$ of full scale. The calibration test will establish the performance characteristics of the transducer.

Performance criteria:

Temperature—0 to +5000 F.

Vibration—random 45 min linear increase from 0.01 g^2 /cps at 10 cps to 0.7 g^2 /cps at 100 cps; constraint at 0.7 g^2 /cps from 100 cps to 500 cps; linear decrease to 0.156/cps at 2000 cps.

Acoustic—11.2 to 11,200 cps at 143 to 118 db (0.0002 dynes/cm²).

Acceleration—20 g for 300 seconds.

Pressure— 1×10^{-6} mm Hg.

Humidity—100%.

Shock—30 g for 11 ± 1 msec.

78 g for 11 ± 1 msec.

Operating life—Per ME 449-0064.

Signal source—self-generating EMF.

Error— $\pm 5\%$ of full scale.

Linearity— $\pm 3\%$ of full scale.

Long-term stability— $\pm 10\%$ for 90 days.



Qualification Tests (Cont)

Resolution— 3% of full scale.
Repeatability— #3% of full scale.
Operating range— max 50 Btu ft²/sec, per ME 449-0064.
Output impedance— not greater than 500 hms into 150K ohms.
Response— per ME 449-0064.

Flight Vehicles

SC 009: first usage and supports subsequent vehicle usage.

Off-Limits Tests

A minimum of ten units will be subjected off-limit tests under simulated reentry environment.
Requirements— Combined vibration, temperature, and overpressure:
Vibration: the same as for the qualification test.
Temperature: to be determined.
Overpressure: five times the rated pressure applied as linear increased input or to 12,000 psia— whichever is less.



Standard Pressure Measuring Subsystem MC 449-0070
ME 449-0070

Criticality 3

Effectivity	Test Conditions
Pre-contract	<p>Evaluation tests:</p> <p>Vibration: 25 grms to 2 kc random; 0.5 g²/cps combined with 25 g (peak) sinusoidal.</p> <p>Thermal shock: -65 to 200 F change in 70 sec or less.</p> <p>Thermal stability: -65 F for 4 hrs; +200 F for 4 hrs.</p> <p>Vacuum: 1×10^{-6} mm of Hg for 14 days.</p> <p>Acoustics—162 db overall, to 10 kc for 15 min.</p> <p>Mechanical shock: 30 g for 11 msec \pm 1 msec.</p> <p>Acceleration: 20 g (10 min per axis).</p> <p>Hysteresis, linearity, and repeatability—11 point calibration, 3 complete loops.</p> <p>Voltage regulation: 90% full-scale pressure applied; input voltage of 28 VDC varied ± 4v in increments of 0.5v; plot input vs output.</p> <p>Output signal-to-noise ratio: nominal excitation voltage applied and white noise of 250 mv (peak-to-peak) a zero to 10 kc inserted into excitation voltage.</p> <p>Output loading effect and output—</p> <p>Impedance: apply full-scale pressure; 1 megohm in 10 equal steps; open circuit voltage taken to compute output impedance.</p> <p>Stability: 25%, 100% full-scale pressures and ambient pressures applied for as long as 24 hr.</p> <p>Input/output isolation: the high and low of the input are shorted together; the high and low of the output is shorted together; the resistance of these two connections is to be checked.</p>



Effectivity	Test Conditions
Pre-contract (Cont)	Insulation test: insulation resistance checked between all connector pins and specimen case; 50 VDC to be applied for this test.
SC 009 and 011	Acceptance test on production parts Insulation resistance: insulation resistance checked between all connector pins and specimen case; 50 VDC to be applied for this test. Linearity and hysteresis repeatability, and output voltage: checked by three five-point calibrations.
SC 012	Acceptance test on qualification parts: complete acceptance testing before and after qualification testing. Between successive qualification tests, the following acceptance tests will be performed: insulation resistance, isolation resistance, and a calibration. (Refer to Acceptance Tests.) Qualification testing: manned flight level (Refer to Qualification Tests.) Acceptance testing on production parts (Refer to Acceptance Tests.)
SC 014	Same as for SC 012.



Qualification Tests

Level	Test Conditions
Manned Flight	<p>Vibration—random; from 0.0025 g^2/cps at 10 cps to 0.015 g^2/cps at 60 cps; constant at 0.015 g^2/cps from 60 cps to 200 cps. 15 minutes each axes.</p> <p>Acoustics—158 db overall.</p> <p>High temperature—ambient to 200 F in 20 min 200 F for 90 min.</p> <p>Low temperature—ambient to -65 F in 20 min -65 F for 90 min.</p> <p>Acceleration: 20 g -300 secs - in each direction of 3 axes.</p> <p>Mechanical shock—78 g in both directions, 3 axes, 1 msec rise time, 1 msec delay time</p> <p>Combined temperature and vibration—vibrated as above at 200 F for 15 min in each axis repeated at -65 F.</p> <p>Vacuum—pressure of 1×10^{-4} mm of Hg for 100 hrs.</p> <p>High-low temperature vacuum—pressure of 1×10^{-4} mm of Hg, 50 hr at -65 F and 50 hr at 200 F.</p> <p>Salt fog test—salt solution 1% by weight, 48 hr in fog.</p> <p>Oxygen-humidity—95% O₂ at 5 psia, 50 hr; 95% O₂ plus 95% humidity, 50 hrs; chamber cycled for 240 hr 3 to 7 psia; insulation resistance checked and calibration performed after first 50 hr output continually monitored.</p> <p>EMI—MC 999-0002.</p>



Acceptance Tests

Examination of product— Verify materials, design, construction, dimensions, and markings.

Insulation resistance— 100 VDC between each connector pin and case; resistance is to exceed 100 megohms.

Input to output isolation— Input leads shorted together; output leads shorted together; 100VDC across these two connectors—resistance is to exceed 100 megohms.

Noise feedback— With 28 VDC provided to specimen, peak-to-peak voltage level indicated on oscilloscope is indicated. Signal is passed through 20 kc low-pass filter before being displayed on oscilloscope. Noise voltage level is not to exceed 10 mv peak-to-peak to 20 kc.

Output regulation— Specimen pressured to 50% full scale; with input voltage varied from 28 to 32 VDC, output reading is not to vary more than ± 10 MVDC.

Input current— With 28 VDC applied to specimen, input current is to be recorded and is not to exceed 56 ma.

Output noise test— 28 VDC to specimen, output indicated on oscilloscope is not to exceed 10 mv peak-to-peak to 10 kc.

Calibration— 7 points, increasing and decreasing, two loops; end points, repeatability, hysteresis, and linearity will be established.

Acceptance vibration— sinusoidal from 5 cps to 2 kc and back to 5 cps; 5 g peak-to-peak for 5 min in one axis.

High temperature— 200 F for 45 min; after exposure check end points.

Low temperature— -65 F for 45 min; after exposure the end points are checked.

Off-Limits Tests

A minimum of three units will be subjected to off-limit tests under simulated flight environment.

Requirements— Combined vibration, temperature, and overpressure:

Vibration: same as for qualification test

Temperature: -65 F and +200 F

Overpressure: five times rated pressure applied as linear increased input or to 12,000 psia—whichever is less.



Nuclear Particle Detection Subsystem MC 431-0040

Criticality 3

Effectivity	Test Conditions
Pre-contract	<p>Development tests: (1) environmental proof (most severe of qualification tests) and (2) nuclear particle development tests. All tests to be performed by subcontractor according to test plan to be submitted to NAA for approval by 1 February 1965.</p> <p>Engineering evaluation: (1) performance checks and (2) systems integration.</p> <p>Electrical testing and combined system checks.</p>
SC 017, 020, 101 to 112, 2H-1, 2TV-1	<p>Qualification tests (4 units)</p> <p>Shock: 30 g for 11 msec.</p> <p>Vibrations: 0.012 to 0.1 g²/cps, 10 to 2000 cps; 15 min each axis.</p> <p>Acoustics: 146 db, 11 to 11,200 cps.</p> <p>Leakage: 34. 10⁻⁶ cm³/ft³/hr.</p> <p>Electromagnetic interference: per MC 999-0002, Table II, D1, D2, D4, D7.</p> <p>High temperature: 140 F, 4 hr.</p> <p>Temperature and vibration: 125 F vibration per paragraph 4.4.2 of specification.</p> <p>Temperature vacuum: 10⁻⁶ mm Hg, 100 hr: -65 F for 50 hr, 125 F for 50 hr.</p> <p>Mission life test (1 unit): 399 hr at laboratory ambient, 1 cycle per paragraphs 4.4.7 and 4.4.8 of specification, plus 800 hr at laboratory ambient.</p> <p>Off-limit vibration (1 unit): per paragraph 4.4.2, except 5 min per axis and step increases from 1.5 x intensity of paragraph 4.4.2 test-to-failure or 2.25 x intensity of paragraph 4.4.2 test.</p> <p>Off-limit temperature (1 unit): per paragraph 4.4.6 except temperature increased in 25 F intervals to failure or 250 F.</p>



Effectivity	Test Conditions
All units: SC 017, 020, 101 to 112, 2H-1, 2TV-1	<p>Acceptance tests</p> <p>Vibration: 10 to 300 cps at 2.5g; 300 to 2000 cps at 5g; 10 min.</p> <p>Examination of product: per ME 431-0040.</p> <p>Performance tests: 4-point calibration.</p>
	<p>Notes: 1. Acceptance tests performed by sub-contractor according to test plan to be submitted for NAA approval by 1 April 65.</p> <p>2. Qualification tests performed by sub-contractor according to test plan to be submitted for NAA approval by 15 June 65.</p> <p>3. The qualification test levels and conditions described are thought to be necessary and sufficient for all manned vehicles.</p>



Water pH Monitor MC 432-0100
ME 432-0100

Criticality 3

Effectivity	Test Conditions
Pre-contract	<p>Development tests: consisted of subjecting preliminary pH monitors to the most difficult and significant criteria of the qualification tests.</p> <p>Operating temperature: ambient temperature 30 F to 140 F; working fluid temperature 200 F.</p> <p>Low temperature storage: -20 F for 10 hr.</p> <p>Shock: drop sensor and signal conditioner onto concrete floor from height of 2 ft.</p> <p>Functional checks: A 3-point calibration will be undertaken after each test.</p> <p>Prequalified parts are used in fuel cell system tests.</p> <p>Fuel cells are operated under simulated power load condition.</p> <p>Note: These tests are valuable in that a functional comparison can be made between the Pratt-Whitney and Beckman pH monitors.</p>
SC 008, 009, 011	<p>Qualification tests:</p> <p>Operating temperature: ambient temperature 30 to 140 F; working fluid temperature raised to 210 F.</p> <p>Low temperature (storage): -20 F for 10 hr.</p> <p>Shock: 30 g, 1/2 sine, for 11 msec. Refer to Procedure II, Method 516 of Mil-Std-810.</p> <p>Vibration: CM vibration levels 0.02 g²/cps at 10 cps, 0.1 g²/cps at 100 cps; constant at 0.1 g²/cps from 100 to 250 cps with a linear decrease to 0.012 g²/cps at 2000 cps.</p> <p>Humidity: Mil-Std-810, Method 507 except max temperature = 140 F.</p>



Effectivity	Test Conditions
	<p>Vacuum: 10^{-6} mm Hg, working fluid temperature = 210 F.</p> <p>Operating life: max environments, work fluid temperature pressure 710 F at 90 psig; ambient temperature 140 F; test period 400 hr.</p> <p>EMI test: tested in accordance with MC 999-0002, paragraphs 4.3.4.11, 4.3.4.3, 4.3.4.4.</p> <p>Calibration: 3-point calibration pH values 4.01, 6.86, 9.18.</p> <p>Impedance check: increase should be less than 600 signal conditioner.</p> <p>Performance test: vendor acceptance test procedure.</p> <p>Calibration: 3-point calibration pH values 4.01, 6.86, 9.18.</p> <p>Response time: pH of 5 applied suddenly to sensor.</p> <p>Impedance check: measure output impedance of signal conditioner.</p> <p>Note: This qualification test is more extensive than necessary for SC 008 parts; but for the sake of economy and simplicity, only one set of qualification test parameters is listed for the pH monitor.</p>
SC 008	Mission thermal environment tests to be conducted at MSC under the supervision of NAA.
SC 012 and subsequent vehicles	<p>Qualification test: utilization undetermined; no qualification tests being implemented.</p> <p>Note: The Beckman pH monitor (MC 432-0100) was procured as a backup system for the operational transducer supplied with the fuel cell. A decision will be made by the fuel cell group concerning the relative merits of the two systems. Further procurement of this pH monitor is dependent on that decision. Presently, these parts have been procured for SC 008, 009, and 011 only.</p>

Laboratory Systems

3 point calibration: output 0 to 5 V and sensitivity 833 MV per pH.



Major Ground Tests

Units installed in NAA/S&ID laboratory fuel cell tests setup to verify operation under simulated space installation condition.

Flight Vehicles

Undetermined to date.



Gas Chromatograph (GFE)
NASA 5.24.1.1.1

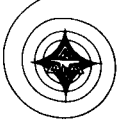
Effectivity	Test Conditions
Pre-contract	Development tests: the gas chromatograph is being procured by NASA from MELPAR, Inc. Basic studies and subsequent development tests were conducted throughout fabrication of the instrument's individual components. NAA was given copies of the supplier's monthly progress reports. NAA representatives felt that the developmental tests were complete and sufficient.
SC 008, 011, 012, and 014	<p>Qualification tests: qualification test procedures were submitted to NASA by the subcontractor. A copy of the "Statement of Work" which defines the capabilities and environmental testing to be undertaken by the subcontractor was given to NAA by NASA. The following is a list of the environmental levels and tests specified for the instruments per NAS9-2518. Two instruments are to be subjected to all these environments.</p> <p>Altitude: they will be subjected from -20 F to 140 F at an altitude of 35,000 ft (non-operating) for 8 hours, the time being equally divided between the temperature extremes.</p> <p>Rain: they will be subjected to as much as 0.6 in./hr for a period of 12 hours, or per Mil-Std-810 Method 506 in protective covering.</p> <p>Sand and dust: they will be subjected to 140-mesh silica flour with particle velocity up to 500 ft/min or Mil-Std-810, Method 510 in protective covering.</p>



Effectivity	Test Conditions														
SC 008, 011, 012, and 014 (Cont)	<p>Salt spray: they will be subjected to 20% salt solution for 50 hr or Mil-Std-810, Method 509 in protective covering.</p> <p>Electromagnetic interference: instruments will be tests in accordance with specification MC 999-0002 B.</p> <p>Explosion proof: instruments will be tested in accordance with MSFC Dwg 10M101071.</p> <p>Launch and entry (operating):</p> <p>Acceleration: instruments will withstand 7.0 g on its X-axis and ± 5.1 g on its Y- and Z-axis for 5 min each; 20 g on its X-axis for one minute duration.</p> <p>Vibration: they will be operable after exposure to the following vibration levels in each of three mutually perpendicular axis. The vibration time will be 15 min random vibration with a 5-min superimposed sweeping sinusoidal vibration. All resonant frequencies will be reported.</p>														
SC 008, 011, 012 and 014	<p>Random vibration hi-Q abort: 5 to 60 cps linear increase from $0.006 \text{ g}^2/\text{cps}$ to $0.13 \text{ g}^2/\text{cps}$, 60 to 200 cps constant at $0.13 \text{ g}^2/\text{cps}$, 200 to 2000 cps linear decrease from $0.13 \text{ g}^2/\text{cps}$ to $0.006 \text{ g}^2/\text{cps}$.</p> <p>Peak vibration, hi-Q abort: 5 to 15 cps linear increase from 0.3 g to 2.0 g, 15 to 100 cps linear increase from 2.0 g to 11 g, 100 to 2000 cps constant 11 g.</p> <p>Acoustics: they will be capable of operating within specifications after exposure to acoustic noise levels as specified herein. Sound pressure level (db) reference 0.002 dynes/cm^2.</p> <table data-bbox="773 1625 1372 1853"> <thead> <tr> <th>Octave Band (cps)</th><th>Level (db)</th></tr> </thead> <tbody> <tr> <td>4.7 to 9.4</td><td>131</td></tr> <tr> <td>9.4 to 18.8</td><td>132</td></tr> <tr> <td>18.8 to 37.5</td><td>135</td></tr> <tr> <td>37.5 to 75</td><td>134</td></tr> <tr> <td>75 to 150</td><td>134</td></tr> <tr> <td>150 to 300</td><td>131</td></tr> </tbody> </table>	Octave Band (cps)	Level (db)	4.7 to 9.4	131	9.4 to 18.8	132	18.8 to 37.5	135	37.5 to 75	134	75 to 150	134	150 to 300	131
Octave Band (cps)	Level (db)														
4.7 to 9.4	131														
9.4 to 18.8	132														
18.8 to 37.5	135														
37.5 to 75	134														
75 to 150	134														
150 to 300	131														



Effectivity	Test Conditions	
SC 008, 011, 012, and 014 (Cont)	Octave Band (cps)	Level (db)
	300 to 600	129
	600 to 1200	130
	1200 to 2400	129
	2400 to 4800	126
	4800 to 9600	122
	Overall	142
	Temperature: the instruments will be subjected to -15 F exposure for 96 hours while operating in accordance with its duty cycle. Shall be subjected to 200 F for 15 minutes (nonoperative).	
	Humidity: there will be 95±5% relative humidity including condensation in a temperature range of 30 to 150 F for a period of 14 days. Temperature shall be cycled over the ranges given.	
	Spaceflight: they will be capable of operating during and after exposure to the following environmental conditions.	
	Hazardous gases: explosion proof per MSFC Dwg 10M01071.	
	Altitude: 1×10^{-4} mm Hg for 96 hr.	
	Earth-impact: shock—they will be capable of sustaining earth-impact shock in any direction without causing or becoming a secondary projectile or leaking. 78 g for 11 ± 1 msec will be used as the shock input.	
	Oxygen compatability: 14.7 psia for 4 hr and 5 psia for 496 hr.	
	One unit is subjected to a second cycle of the same environment as an endurance test; the other unit, to overstress testing.	
	Laboratory systems: calibrations will be conducted by the subcontractor during the acceptance tests and also by NASA.	
	Major ground tests: the SC 008's thermal environment tests will verify the integrated systems operation and operating procedures. NAA will evaluate operation and will validate for flight usage. SC 008 is first usage and supports subsequent flight vehicles.	



Effectivity	Test Conditions
SC 008, 011, 012, and 014 (Cont)	Flight vehicles: these tests will further qualify the instrument's flight worthiness under lift-off and reentry conditions, will further test the helium dump capability under pad abort conditions, and will verify this operation at reentry. SC 011 is first usage and supports subsequent flight vehicles.



Commutator (GFE)

Criticality 3

Effectivity	Test Conditions
Block I: SC 006, SC 008, SC 009, SC 011, SC 017, SC 020	Procured by NASA MSC-IESD; qualified for all spacecraft mission environments and classified as man-rated per NASA-IESD document 19-1A. (Refer to Pre-Delivery Development Test.) Perform pre-installation operational checkout (NAA effort). Perform breadboard integrated systems design compatibility test (NAA effort). Note: Program as defined here adequately qualifies item for all spacecraft mission requirements.
Block II	None.

Qualification Tests—Environments

Pre-Delivery Development Tests
(NASA-Supplier Effort)
IESD Document 19-1A

Temperature—30 F to +230 F.
 Altitude— 1×10^{-6} mm Hg pressure or less.
 Acceleration—20 g in each direction of 3 mutually perpendicular axes.
 Shock—50 g for a period of 11 ± 1 msec, 1/2 sine shock impulse.
 Acoustic noise— 165 ± 1 db (ret to 0.0002 dynes/cm² for a period of 5 min.
 Spectrum: 165 db, 22.4 to 1.200 cps.
 Vibration—15 g rms for 15 seconds: 0.1607 g²/cps, 10 to 220 cps;
 0.0573 g²/cps, 220 to 2020 cps.
 O₂ atmosphere—100% at 7 psia.
 Salt fog—5% salt spray per Mil-Std-810 (USAF), Method 509.
 Humidity—100% relative humidity, 80 to 150 F per Mil-Std 180 (USAF),
 Method 507.
 EMI—Per Mil-I-26600/MSC-EMI-IDA.



PAM/FM/FM Telemetry (GFE)

Criticality 3

Effectivity	Test Conditions
Block I: SC 008, SC 009, SC 011, SC 017, SC 020	Procured by NASA MSC-IESD; qualified for all spacecraft mission environments and classified as man-rated per NASA-IESD document 19-1A (Refer to Pre-Delivery Development Test.) Perform pre-installation operational checkout (NAA effort). Perform breadboard integrated systems design compatibility test (NAA effort). Note: Program as defined here adequately qualifies items for all spacecraft mission requirements.
Block II: SC 101	Development program is the same as for Block I.
Qualification environments Temperature— -30 F to +230 F. Altitude— 1×10^{-6} mm Hg pressure or less. Acceleration—20 g in each direction of 3 mutually perpendicular axes. Shock—50 g for a period of 11 ± 1 msec, 1/2 sine shock impulse. Acoustic noise— 165 ± 1 db (ret to 0.0002 dynes/cm ² for a period of 5 min. Spectrum: 165 db, 22.4 to 11,200 cps. Vibration—15 g rms for 15 sec: 0.1607 g ² /cps, 10 to 220 cps; 0.0573 g ² /cps, 220 to 2020 cps. O ₂ atmosphere—100% at 7 psia. Salt fog—5% salt spray per Mil-Std-810 (USAF), Method 509. Humidity—100% relative humidity, 80 to 150 F per Mil-Std-180 (USAF), Method 507. EMI—Per Mil-I-26600/MSC-EMI-10A.	



APPENDIX A
OPERATIONAL INSTRUMENTATION COMPONENTS

To be added at a later date.



APPENDIX B
FLIGHT DEVELOPMENT INSTRUMENTATION COMPONENTS

To be added at a later date.



APPENDIX C
SPECIAL INSTRUMENTATION COMPONENTS

To be added at a later date.



APPENDIX D
SCIENTIFIC INSTRUMENTATION COMPONENTS

To be added at a later date.